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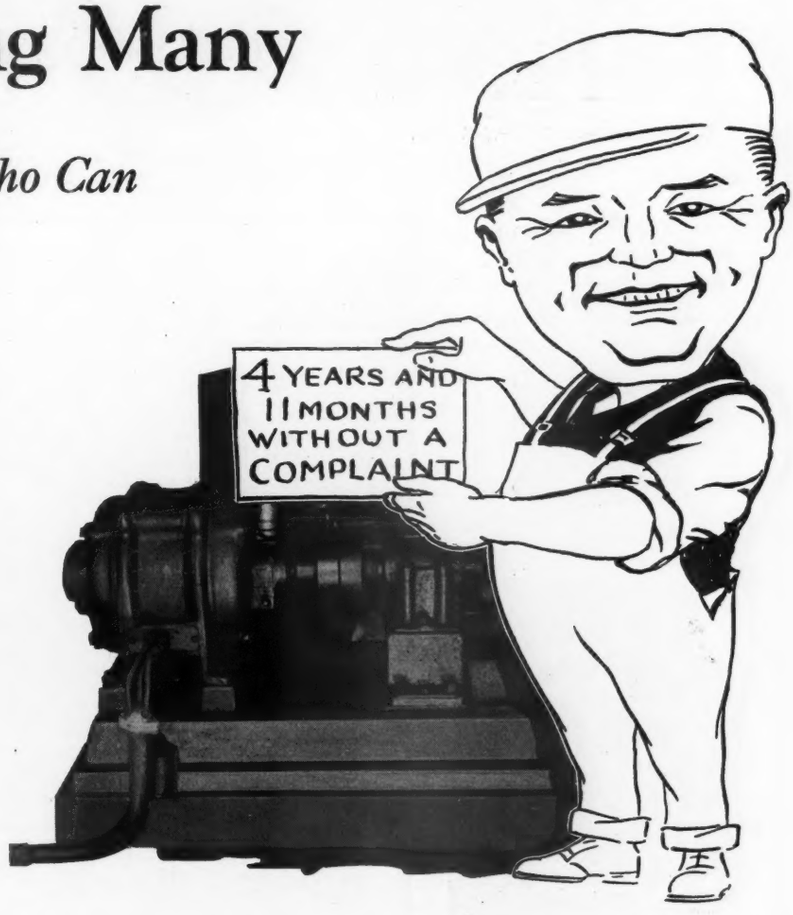
A Good Record–But Surely One Among Many

Is There Someone Who Can Go Sawyer One or Two Better?



DOWN in the "witch" city of Salem, Mass., is a 5-hp., 40-deg., three-phase, 1800-r.p.m., 60-cycle induction motor that has been running continuously day and night, weekdays and Sundays, since Oct. 1, 1917. It has been down once a year for a half hour in order that the direct-connected brine pump which it drives may be provided with new packing. But not a cent has been expended upon this motor for repairs during this period, and the only outlay chargeable to it has been for new oil.

Fred E. Sawyer, power engineer of the Salem (Mass.) Electric Lighting Company, who sent the accompanying photograph, makes no claim that this record cannot be beaten, but he sort of infers that he would like to hear from the fellow who can show a better one. So would I.

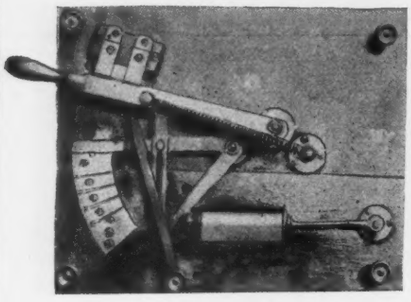
You know the question has often been asked me, "How old must a motor be to be positively and undeniably placed on the retired list?" I'll be thirty-nine years old shortly and I have to admit that I shall have to plod on some time yet or depend upon some of you "older" (in years) fellows to give the answer. If we consider that the first motors were placed in service around 1885 the period of operation to look back over is only thirty-seven years, and surely many practical men (with ambitions still young) can recall several motor installations that have lived to a good old age. Let's get a list of these together and see what kinds of machines they are connected to.

But don't overlook Sawyer's five-year-old (lacking one month) that hasn't cost him a cent. Can you go him one or two better?

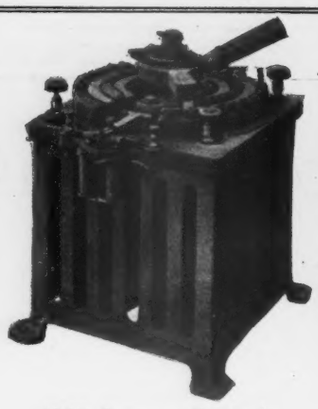
Practical Pete

Starters For Direct Current Motors

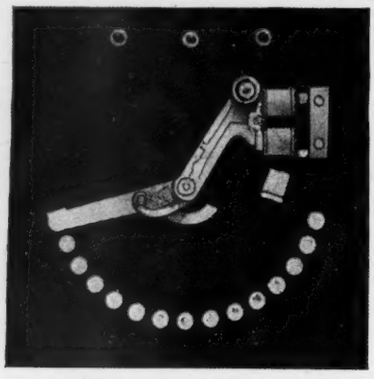
Some Early and Present Day Types



1888 AUTOMATIC SWITCH CO.



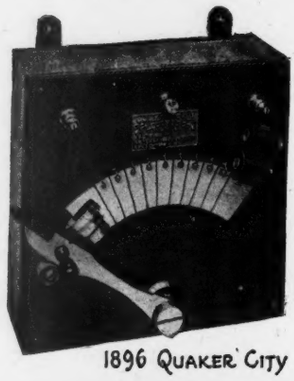
1893 GENERAL ELECTRIC



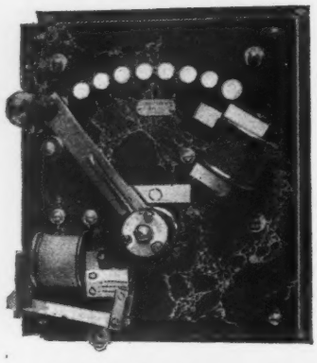
1894 CARPENTER

1896 C AND C

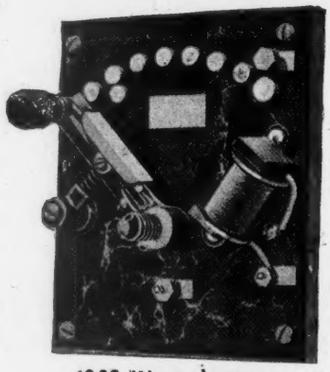
WHEN motors were first used they were connected directly to the line, but the desirability of limiting the starting current was soon realized. Probably the first starter manufactured in this country was that of Leo Daft, designed in 1886. This switch had only one step of starting resistance and was operated by means of a cam manually driven through a worm gear. This cam could be driven only at a slow speed, so that the starting resistance was in circuit long enough to allow the motor to reach the proper speed before being directly connected to the line. This starter also had an overload relay. A starter made by the Automatic Switch Company in 1888 had several resistance steps and employed a dash pot to insure a slow movement of the contact arm in accelerating the motor. One of the first starters to employ the no-voltage release was that made by the General Electric Company in 1893. Since that time the changes in design have mostly pertained to automatic operation. Solenoids and gears driven by the motor shaft have been used since about 1894 to move the contacts. The principle of the "counter-electromotive-force" starter was embodied in a starter of the Monitor Controller Company in 1907. Since then current-limiting relays have been adopted by some makers for acceleration of the motor. These relays, in series with the armature, cut out a step of resistance when the current drops to a certain value.



1896 QUAKER CITY



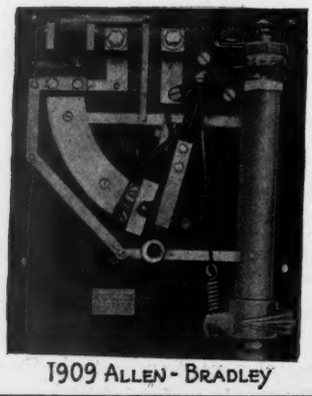
1896 CUTLER-HAMMER



1902 WARD LEONARD

1905 SUNDH

1909 MONITOR



1909 ALLEN-BRADLEY

THE USE of the electric current for fastening together small metal parts, by the process known as spot welding, is finding increasing application as a substitute for riveting, staking and other methods of this nature. This article describes the special electrodes and the details of the procedure whereby 1,000 welds an hour are made in the manufacture of steel grease cups at the plant of the E. N. Garrison Manufacturing Company.

Things That Can Be Done in

High-Speed Welding of Small Parts

By the Use of Semi-automatic Electric Spot Welding Machines

By E. H. HUBERT
Associate Editor, Industrial Engineer

This semi-automatic spot welding machine makes 1,000 welds an hour. The parts are assembled on a revolving dial seen in front of the operator's hands

ELECTRIC spot welding of small manufactured parts offers, in many cases, the three great advantages of: (1) Speed, (2) economy and (3) reliability of work. An interesting application of this process where all of these advantages are obtained may be seen in the plant of the E. N. Garrison Manufacturing Company, Bridgeport, Conn. This company has obtained very good results in spot welding steel grease cups and it is possible that a description of the methods which they employ may be of value to other companies who wish to consider spot welding as a substitute for riveting or other means of fastening thin metal parts together.

The pieces which comprise the grease cups manufactured by this company are small and the metal is approximately 1/16 in. thick. The method used in uniting the parts is known as the electrical resistance method wherein a current of low voltage and large volume is caused to flow through the parts from one electrode to another, while under pressure, until a welding temperature has been reached. Slight projections are raised upon one of the surfaces so that the contact between the two metal parts is at first made only at points instead of on large areas. The machine that has been used successfully is made by Taylor Welder Company, Warren, Ohio. It is a special machine rated at 30 kva., 440 volts, 60 cycles, type M 6. It operates automatically and is driven by a 1-hp., 220-volt motor.

Any ordinary steel which is not too high in carbon may be employed for welding. The carbon should be not over 0.30 or 0.35 per cent. A higher percentage of carbon will result in brittle spots near the weld.

The material to be welded should be kept free from rust and hard, gummed grease. As soon as the metal comes to the factory it is coated with oakite drawing compound. This keeps it from rusting. If the metal has been received from the mills in a clean condition, no other treatment is necessary during drawing and welding. If the metal is rusty it is pickled in acid and cleaned in water before the drawing compound is applied. If the metal is covered with heavy grease which has become gummy, it is treated with an oakite metal-cleaning compound and afterward coated with the drawing compound.

The metal is then drawn and stamped. In order that the welds may be strong, the projecting parts

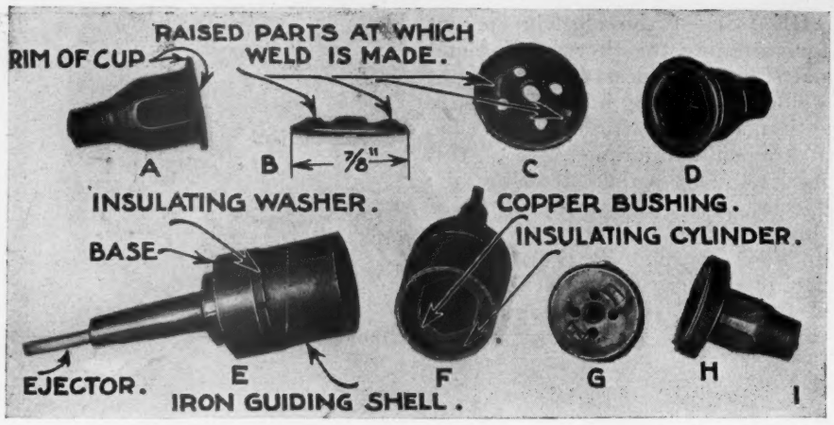


Fig. 1—Small steel parts which are successfully spot welded.

A and *D* show a grease cup to which the rims *B* and *C* are welded. The complete job is shown in *G* and *H*. The last two pictures also show a washer which is added after the weld is completed. At *E* and *F* are shown a combination electrode and holder used in this welding job. The cup *D* and the disk *B* are placed in the electrode. The upper electrode makes contact with the top surface of the disk. Notice how the two projections are made on *B* and *C*. These two points make contact with the flat surface of the cup *B* and through them the current first flows, thus starting the weld.

of the metal which come into contact when the welds are being made must be of the correct shape and size. After a good deal of experimenting it was found that there must be practically a point contact for starting the weld. Melting begins at this point and a larger surface is then brought into contact by pressure. The shapes of the surfaces before welding are shown in Fig. 1 and Fig. 3. Fig. 1 shows the parts of a small grease cup. The rim of this cup shown at *B* and *C* of Fig. 1 is made of steel, 0.049 in. in thickness. It is ⅞ in. in diameter. The parts at which the weld is made are raised about 1/16 in. at the center points. They are each about 5/16 in. long and ⅛ in. wide. While the weld is being made this disk is held against the body of the cup, which is shown at *A* and *D*, with the raised portions touching the flat rim of the cup. The body of the cup is inserted into the electrode shown at *E* and *F*, a disk is placed on top of the cup and another electrode comes down on top of this disk as shown in Fig. 5. The voltage from one electrode to the other for welding this particular cup is 2.1 volts and the current of about 2800 amp. is allowed to flow for 1½ seconds. The pressure which the upper electrode exerts on the disk which is being welded is 45 lb. Pictures of the finished cup are shown in *G* and *H* of Fig. 1. For heavier pieces of metal a greater current is allowed to flow. Another grease cup made has a disk 1⅛ in. in diameter and is formed of 0.055-in. metal. The raised parts on this disk are about 1/16 in. high in the middle by 5/16 in. long and 3/32 in. wide. The potential used in making this weld is 2.5 volts and the current is 3000 amp. which is applied for 1½ seconds.

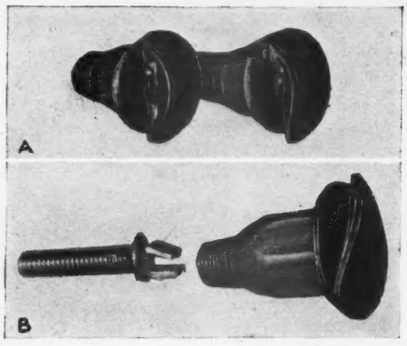


Fig. 2—These electrically welded pieces had to be bent out of shape before the weld would break.

The parts were clamped in a vise and an attempt was made to separate the welds with a cold chisel. The illustration shows that the metal was bent and even torn before the welds broke, so strong is the union between the welded parts.

In experimenting on this work it was found that if two flat surfaces were brought together before the current was passed the weld was not strong. However, by having the projections rounded so that only one point touches at first, this point fuses completely and the heat spreads to the other parts which are brought into contact as the pressure of the electrode forces the pieces together. Experiments were made to determine how many of these projections are needed to give the best weld. It was found that two were most satisfactory, although it is thought that three might be better if a heavier welding machine were employed.

The bottom electrode (Fig. 1) serves two purposes. It holds the parts in the correct position for welding and, of course, it serves to conduct current to the parts to be welded. It must be correctly insulated both for electric current and heat. The current should pass from the rim of the cup into the disk and then into the top electrode. It should not be made to travel a long path, as for instance through the entire body of the cup. The bottom electrode is placed in the electrode holder in an upright position as shown in Fig. 5. Current enters the tapered copper rod which fits into the electrode holder and passes up through the base of the electrode into a copper bushing which is shaped to receive the body of the cup. The rim of the cup rests upon the smooth top surface of this bushing, which is shown in *F* of Fig. 1. The disk which is to be welded onto the body is then placed on top of the body, and in order that it may be placed in the right position an iron

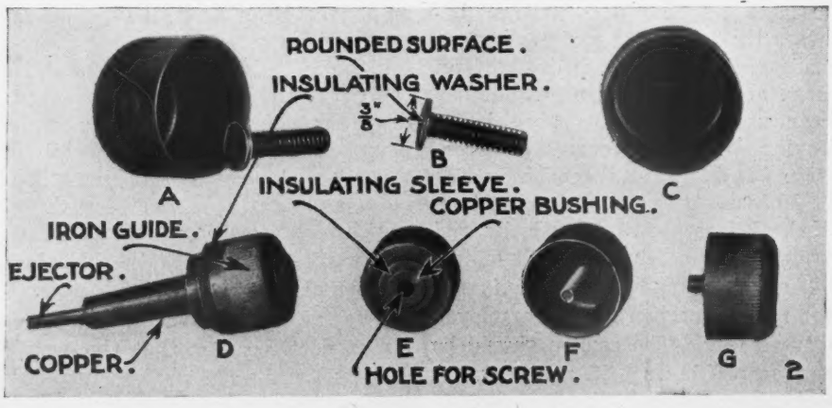


Fig. 3—A screw welded on the flat surface inside the top of the grease cup.

A, *B* and *C* show the parts before welding, while at *F* and *G* is a cup with the screw welded in place. At *D* and *E* is the holding electrode used for a die and as a current carrier. Notice that the surface of the screw head is rounded so that it makes contact with only one point on the flat surface of the top as the weld is started.

guiding shell is fitted onto the electrode. This shell is insulated at its bottom end by a fiber washer and is insulated from the copper bushing by a fiber cylinder as shown in *F* of Fig. 1. The disk fits loosely inside of the shell but accurately enough in place on top of the cup. After the weld is made the cup is pushed out of the electrode by means of the ejector rod which is shown at *E* of Fig. 1. This operates automatically as will be explained later. As there is considerable wear on the copper bushing, due to mechanical abrasion and passage of electric current, this bushing is made so that it may be removed and replaced whenever necessary.

The method by which the screw is welded to the top of the cup is illustrated in Fig. 3. The screw heads used for making the top of the smaller cups are ⅜ in. in diameter and about 1/16 in. thick. The top surface of the screw head is rounded slightly so that only one point may be touching the flat surface of the top when the weld is started. This weld is made at a voltage of 2.1 with a current of 3000 amp., and under 45 lb. pressure. It requires 1½ seconds.

The screws are placed in the holes in the center of the electrode with the flat undersurface of the screw resting upon the flat top of the copper bushing. Surrounding this bushing is an insulating sleeve and around this is a cylindrical iron guide piece for guiding the top into the correct position. This iron guide piece is insulated from the bushing by the sleeving and from the base of the electrode by a fiber washer. After the screw is in position the top is placed over it. The upper electrode is then brought down on the outside of the top.

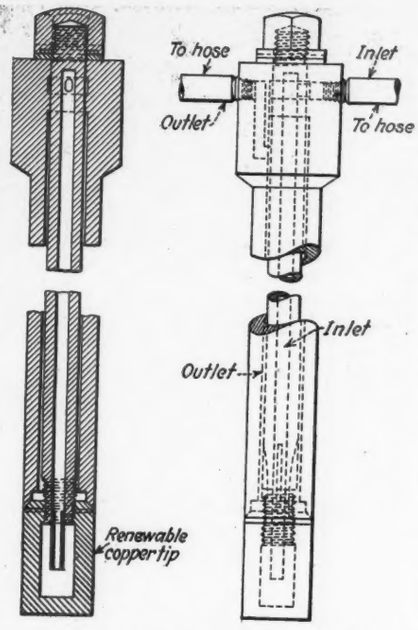


Fig. 4—A water-cooled electrode for spot-welding.

The foregoing covers the details of each welding operation as they are carried out in this plant. The machine is driven by a 1-hp., 220-volt motor and the work is continuous and partly automatic. The parts to be welded are placed on a small, round dial which serves as the bottom electrode. Electrical connection is made to this dial by means of a copper brush which also serves as a brake. This brake bears against the copper band extending around the rim of the dial as shown in Fig. 5 and in the illustration at the beginning of this article. Twelve of the bottom electrodes are placed on this dial and it revolves one step at a time, bringing each electrode in succession underneath the top electrode. When one bottom electrode is underneath the top electrode, the table stops and the top electrode is held down against the material to be welded. After the proper time the electrode is automatically raised and the table shifts around so that the next bottom electrode is in position. As the table continues to revolve the ejector in the bottom electrode strikes a beveled piece of steel underneath. This lifts out the welded pieces, which fall into a receiver at the left-hand side of the operator. When the machine is in full operation two girls are kept busy, one feeding the body of the cups into the electrode while the other puts in the rim pieces. Working in this way the machine makes 1,000 welds per hour. The machine may be operated at six different speeds by means of a gear-changing handle. The range is from 46 to 91 welds per minute. As may be seen from the photograph at the beginning, and in Fig. 4, the upper copper electrode is water cooled. The water is taken to the machine by ½-in. rubber hose.

The transformer has six taps, so that the voltage may be varied from 1.5 volts to 2.5 volts, and takes from 35 to 45 amp. on the 220-volt side.

Although some experimenting was necessary at first, the welds now made by this machine have great strength. On a number of them it has been found that the parent metal would tear before the weld was pulled apart. In Fig. 2 are shown some sample pieces which have been tested. The pieces were clamped in a vise and a cold chisel was used in an attempt to break the weld. As may be seen the metal was bent entirely out of shape before the weld started to give way.

Fig. 5—Revolving dial on which 1,000 welds an hour are made.
The operator feeds the two parts into the revolving electrodes which hold them in the correct position. When an electrode is in place underneath the top electrode the dial stops and the weld is made. It takes about 1½ seconds. The parts are automatically removed by means of the ejector rods which may be seen under the front part of the dial. They strike on a beveled piece of steel which lifts them thus pushing out the finished parts, which are deposited in a box on the further side of the table.

IN THIS ARTICLE Mr. Going explains a method he has devised for making it as easy to determine the size of fuse and feeder for a group of induction motors as for a single motor. He refers especially to those cases where a large motor is included in the group, the starting current of which really determines the size of fuse to take care of the group. The curves can be used for a wide range of practical work in wiring motors and will save a lot of time in making calculations or referring to other wiring tables.

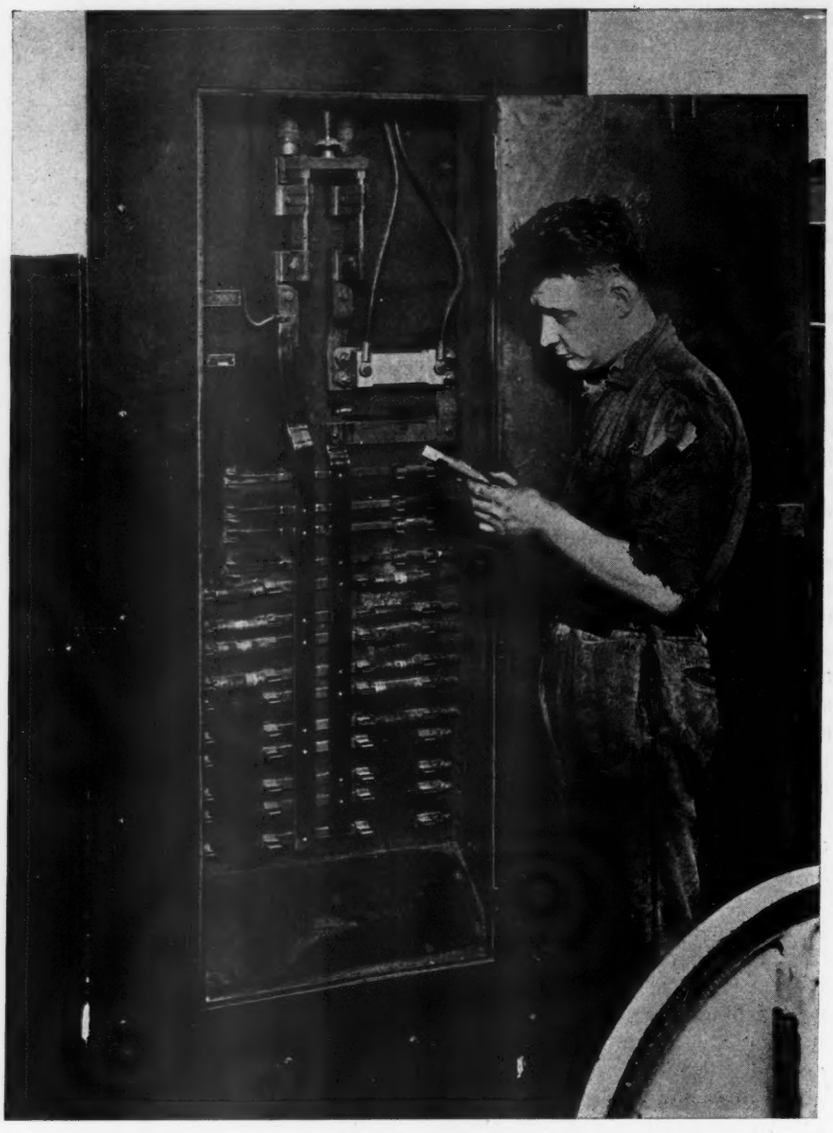
A Simple Method for Selecting the

Size of Fuses For Motors

That Are Connected in a Group to the Same Feeder

By L. W. GOING,

Chief Electrical Inspector, Department of Public Works, Portland, Ore.



IN THE compilation of wiring data for alternating-current motors of the type which takes a heavy starting current, the question of fuse capacity is of extreme importance. The National Electrical Code permits a rubber-covered wire used in a branch circuit carrying the current of only one motor of the type having large starting current to be protected by fuses rated in accordance with Table C of Rule 18 of that code. A rough approximation of the necessary current-carrying capacity of conductors expressed as a percentage of the motor nameplate rating is indicated in Rule 8 of the National Electrical Code as follows:

RATED FULL LOAD CURRENT	PERCENTAGE
0-30 Amperes	250
Above 30 Amperes	200

This rule serves very well as a rough approximation, but does not admit of any flexibility which at times may be desirable when certain known operating conditions exist. The National Electrical Code does not permit Table *C* fusing for conductors carrying the current of more than one alternating-current motor. To insist upon Table *A* fusing of feeders which carry the current of a group of motors may sometimes require a much larger conductor than good practice would seem to indicate. This is particularly true for small groups of motors or for any group where the starting current of any one motor predominates.

The practical value of my method lies in the solution of group motor installations where one large motor is included, the starting current of which really determines the size of fuse necessary to care for the group. Take, for instance, an extreme case, such as a feeder supplying a 100-hp. motor and two 10-hp. motors. Assuming a 220-volt, three-phase supply circuit, the size of fuse necessary would be 500 amp., on the basis of

WHEN USING the curves and method described by Mr. Going these points should be noted:

[1] The table on page 417 will not apply to groups of motors of uniform sizes except possibly for groups of less than three motors.

[2] The curves do not apply when a diversity factor is allowed with motor groups.

[3] The great value of Table *C* is to show that there is an inconsistency in the National Electrical Code when it states in Rule 8, Section *C*, Division 3, 3rd paragraph: "Where rubber-covered wire is used in a branch circuit carrying the current of only one a. c. motor of a type having large starting current and this circuit is protected by fuses, it may be protected in accordance with Table *C* of No. 18," etc. Therefore, because of the large starting current in feeders supplying a group of motors which includes one large motor, it should be possible to use Table *C*, provided normal feeder load does not exceed the Table *A* rating.

a 60-second starting period for the 100-hp. motor with the remaining motors carrying full load. If we follow the ruling of the National Electrical Code, this group would require a feeder of 700,000 circ. mil capacity (Table *A* rating, 500 amp.). Now the actual current in the feeder, except for the short starting period of a large motor, is only 350 amp., figuring 125 per cent load for the 100-hp. motor and normal load for the two 10-hp. motors. A 400,000 circ. mil feeder will carry 325 amp. (Table *A* rating) and would be the economic copper capacity for the installation. The fuse necessary in the feeder because of the heavy starting current of the large motor is 500 amp., which is the Table *C* rating of a 400.000 circ. mil cable.

There is little reason, in a case of this nature, to insist on copper capacity for a continuous load of 500 amp., viz., 700,000 circ. mil, because this is a group motor installation and not the case of a feeder carrying the current of only one a. c. motor of a type having a large starting current, as mentioned in the National Electrical Code. From an inspection standpoint, the larger feeder no doubt makes a good installation, but from an engineering standpoint this large feeder, along with larger conduit, etc., is clearly an economic waste, unless, of course, there is a possibility of further increase in the connected load. Such a possibility, however, is remote in the case of sub-feeders supplying small groups of motors.

It is clear that some knowledge as to the cutout capacity necessary to provide for the heavy surge of cur-

Size and Protection of Conductors of Motor Circuits

(From National Electrical Code, Rule 8, section C, division 3, page 18, 1920 edition)

Conductors carrying the current of only one motor must have a carrying capacity of at least 110 per cent of the nameplate current rating of the motor.

Each conductor carrying the current of only one motor and each ungrounded conductor carrying the current of a group of motors must be protected in accordance with the general requirements for the protection of conductors; that is, the rated capacity of the fuses must not exceed the carrying capacity of the conductors, and circuit breakers must not be set more than 30 per cent above the carrying capacity of the conductors, as given in No. 18. Where rubber-covered wire is used in a branch circuit carrying the current of only one a. c. motor of a type having large starting current and this circuit is protected by fuses it may be protected in accordance with Table *C* of No. 18, but in no case should a rubber-covered conductor in a branch circuit carrying the current of only one motor have a carrying capacity in accordance with Table *A* less than 110 per cent of the nameplate current rating of the motor.

To provide for the large starting currents of certain types of a. c. motors without overfusing the conductors, wires considerably larger than 110 per cent of the motor nameplate current rating may be necessary in that part of the circuit not included in the protection afforded by the motor protective device.

In the great majority of cases where a. c. motors requiring large starting currents are started by means of auto starters, the necessary current-carrying capacity of conductors in that portion of the motor circuit not included in the protection afforded by the motor protective devices will not exceed the following percentages of the nameplate current rating on the motors.

Rated full load current	Percentage
0 to 30 amperes	250
Above 30 amperes	200

In nearly all cases where a. c. motors of the above type are started without auto starters, the necessary current-carrying capacity of conductors in that portion of the motor circuit not included in the protection afforded by the motor protective devices will not exceed 300 per cent of the nameplate current ratings of the motors.

To provide for the peak loads which are encountered in certain classes of service, such as operating valves, raising or lowering rolls, rolling tables, hoists, elevators, pumps, etc., without overfusing the conductors, motors will sometimes require cables considerably larger than 110 per cent of the motor nameplate current rating. In a majority of cases the current-carrying capacity of conductors complying with the rule will not exceed the percentages of the nameplate current ratings of the motors given in the following table:

PERCENTAGE OF NAMEPLATE CURRENT RATING

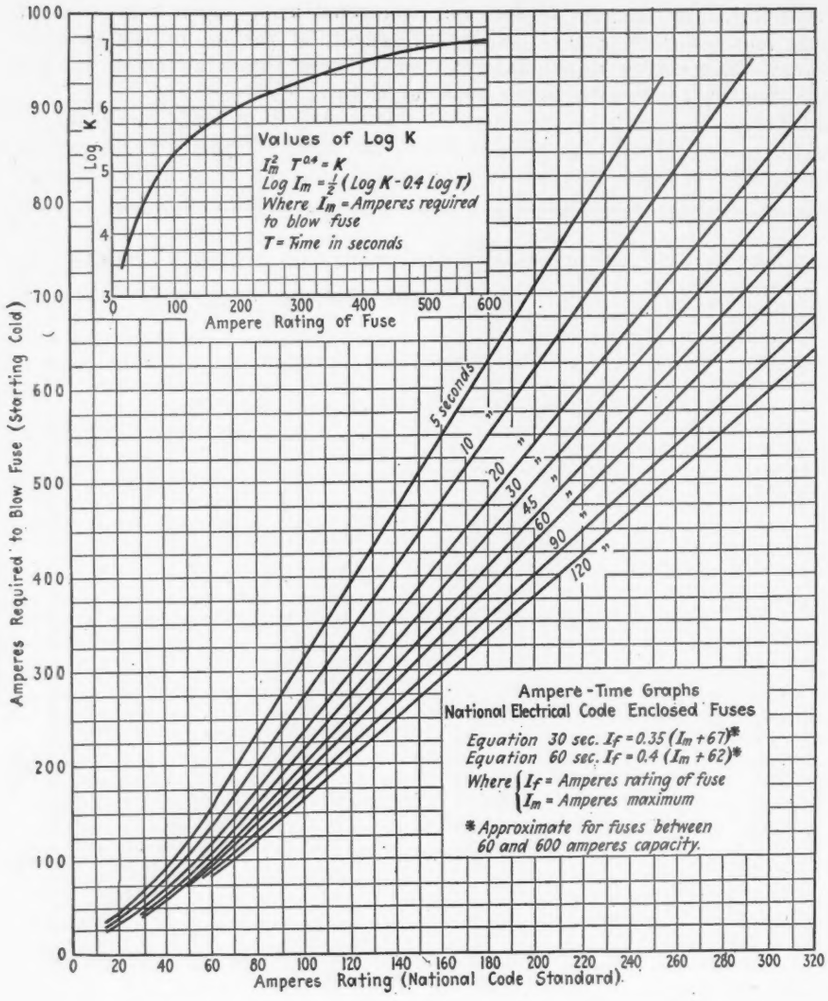
Classification of Service	5 min. rating	10 and 15 min. rating	30 and 60 min. rating	2 hr. rating	Continuous rating
Operating valves, raising or lowering rolls	110	120	150	200	250
Rolling tables	110	120	135	180	200
Hoists, rolls, ore and coil handling machines	110	115	120	150	170
Freight and passenger elevators, shop cranes, tool heads, pumps, etc.	110	110	110	120	140

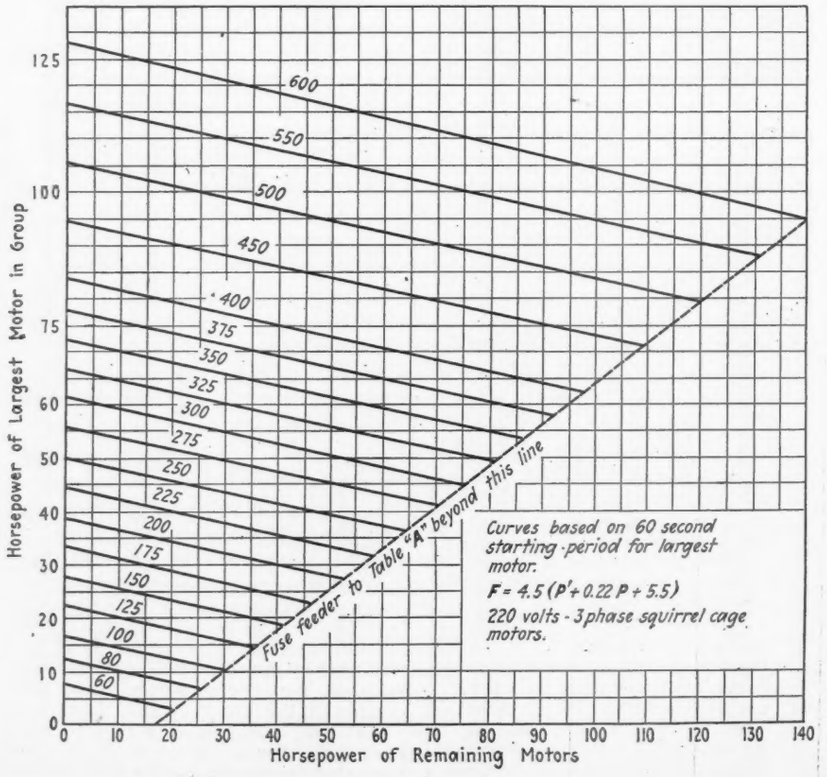
Alternating current motors operating freight or passenger elevators or cranes, that are dependent on phase relation for the direction of rotation, must be protected by approved automatic circuit breakers (or reverse phase relay) operative in the event of any phase reversal that would cause a reverse motor rotation, or in the event of the motor being connected to the line single phase.

Allowable Carrying Capacities of Wires

(From National Electrical Code, Page 44, 1920 Edition)

B. & S. Gage	Diameter of Solid Wires in Mils	Area in Circular Mils	Table A Rubber Insulation Amperes	Table B Varnished Cloth Insulation Amperes	Table C Other Insulation Amperes
18	40.3	1,624	3		5
16	50.8	2,583	6		10
14	64.1	4,107	15	18	20
12	80.8	6,530	20	25	25
10	101.9	10,380	25	30	30
8	128.5	16,510	35	40	50
6	162.0	26,250	50	60	70
5	181.9	33,100	55	65	80
4	204.3	41,740	70	85	90
3	229.4	52,630	80	95	100
2	257.6	66,370	90	110	125
1	289.3	83,690	100	120	150
0	325.	105,500	125	150	200
00	364.8	133,100	150	180	225
000	409.6	167,800	175	210	275
		200,000	200	240	300
0000	460.	211,600	225	270	325
		250,000	250	300	350
		300,000	275	330	400
		350,000	300	360	450
		400,000	325	390	500
		500,000	400	480	600
		600,000	450	540	680
		700,000	500	600	760
		800,000	550	660	840
		900,000	600	720	920
		1,000,000	650	780	1,000
		1,100,000	690	830	1,080
		1,200,000	730	880	1,150
		1,300,000	770	920	1,220
		1,400,000	810	970	1,290
		1,500,000	850	1,020	1,360
		1,600,000	890	1,070	1,430
		1,700,000	930	1,120	1,490
		1,800,000	970	1,160	1,550
		1,900,000	1,010	1,210	1,610
		2,000,000	1,050	1,260	1,670


Values of Log K
$I_m^2 T^{0.4} = K$
$Log I_m = \frac{1}{2}(Log K - 0.4 Log T)$
Where I_m = Amperes required to blow fuse
T = Time in seconds
Log K
Ampere Rating of Fuse
Amperes Required to Blow Fuse (Starting Cold)
5 seconds
10 "
20 "
30 "
45 "
60 "
90 "
120 "
Ampere-Time Graphs
National Electrical Code Enclosed Fuses
Equation 30 sec. $I_f = 0.35 (I_m + 67)$*
Equation 60 sec. $I_f = 0.4 (I_m + 62)$*
Where I_f = Amperes rating of fuse
I_m = Amperes maximum
* Approximate for fuses between 60 and 600 amperes capacity.
Amperes Rating (National Code Standard)



rent on induction motor feeders is essential in arriving at an equitable solution of the above difficulty. For this purpose, some knowledge of the time-limit characteristics of the standard enclosed type of fuse is necessary. The various factors may be designated as follows: I_t=amperes rating of fuse (National Code standard); I_m=amperes required to blow fuse, starting cold; r=radiation constant; K=a constant de-

Fig. 1—Values of constant K and time required to blow fuses under a given overload.

It is necessary to take into account the radiation constant r in calculating the amount of heat retained in the fuse wire, because the heat loss varies with the time, T. The expression for K is then: $(I_m - I_t)^2 Tr = K$ or, log. $(I_m - I_t) = \frac{1}{2}$ (log. K — r log. T.) For the graph of a 100-amp. fuse this equation reduces to: log. $(I_m - I_t) = \frac{1}{2}$ (5.257—0.77 log. T). Values obtained from this equation check very closely with the experimental curve for values of T from 10 seconds to 5 minutes. An expression in terms of I_m and T which gives very good results for all capacities of fuses from 60 to 600 amp. throughout the range of practical importance in motor calculations, viz., where T ranges between 10 and 120 seconds, and for fuses below 60 amp. capacity when T is less than 60 seconds, is as follows: $I_m^2 T^{0.4} = K$, or log. $I_m = \frac{1}{2}$ (log. K—0.4 log. T). The values of log. K as determined by experiment are shown in the curve in the upper left corner of the illustration. The curves in the lower portion of the illustration give the blowing time for various sizes of fuses under given overloads. If it is desired to find the size of fuse required to carry 325 amp. for 20 seconds, trace the horizontal line corresponding to 325 amp. to its intersection with the curve marked "20 seconds." Then trace downward the vertical line nearest this point of intersection. In this instance the value of the vertical intersecting line is 130, which is the ampere rating of the fuse required. Conversely, to determine the current which will blow a 140-amp. fuse in 30 seconds, trace upward the vertical line whose value is 140, to its intersection with the curve marked "30 seconds." Then tracing to the left the horizontal line nearest to this point, it is found to have a value of 325, which is the number of amps. required to blow this fuse in the given period.

Fig. 2—Fusing requirements for feeders which supply more than one motor.

These curves are based on Equation 7 in the text and show when the feeders should be fused in accordance with Table A of the National Electrical Code. To use these curves, trace the horizontal line corresponding to the horsepower of the largest motor to the point of intersection with the vertical line corresponding to the horsepower of the remaining motors of the group. If the point where these lines cross is to the right of the diagonal dotted line, the feeder can be fused as shown in Table A of the Code. The crossing point of the lines when it falls to the right of the dotted line indicates that a fuse rated to carry normal full-load current of the motors will also have sufficient time limit properties to care for the starting current of the largest motor. If the intersection of the two lines is to the left of the dotted line, the size of fuse to be used is indicated by the solid diagonal line nearest to the intersection. The numbers above these lines correspond to the fuse rating in amperes.

Steps in Figuring Feeder Sizes for Groups of Motors

In calculating the size of feeders for group motor installations:

[1] Determine the normal load on the feeder and select the size of conductor from Table *A* (page 417). For small groups this load should be taken on a basis of 110 or 125 per cent of the rating of the largest motor plus full load currents of the others.

[2] Determine the size of fuse necessary to carry the starting current of the largest motor plus the load of the remaining motors. This fuse should not exceed Table *C* rating of the conductor chosen. If such fuse exceeds the Table *C* rating, the next larger size conductor should be used.

[3] In any installation where a demand factor is permitted, the feeder fuse should never exceed Table *A* rating, which is the proper protection for a rubber-covered conductor under continuous load conditions.

pending upon the capacity of fuse; T=time in seconds required to blow fuse. On the assumption that the number of heat units necessary to melt any given capacity of fuse is a constant quantity, it is possible to form an equation which will very closely approximate the blowing curve.

The values of log K for the various fuse capacities as determined by experiment are indicated in the upper corner of Fig. 1. The curves in the lower portion of Fig. 1 have been computed and give the time required to blow the various sizes of fuses under specified overloads. The interesting feature of these curves is that they are practically straight lines for fuses above 60 amperes capacity. This fact enables us to write a simple equation for any of the time curves, for example:

(1) I_t=0.35 (I_m+67), for 30-second curve.

(2) I_t=0.4 (I_m+62), for 60-second curve.

These equations give very close results for fuses from 60 to 600 amperes capacity.

To apply these results in the calculation of motor wiring problems, the approximate value and duration of the starting current must be known. For constant-speed, squirrel-cage motors the maximum current ranges from 6 to 9 times the normal full-load value and the effective value (root-mean-square) during the starting period will average between 5 and 7 times normal full-load current. The heating of the fuse is of course determined by the effective value of the current during the period of starting.

As an example, a 5-hp., 220-volt, 3-phase motor having a normal rating of 14 amp. may be taken. Assume that this motor is thrown directly on the line and that the effective value of the starting current is 6 times 14 amp., or 84 amp., over a period of 5 seconds. Referring to the ampere-time graphs in Fig. 1, it is seen that a 40-amp. fuse will carry 95 amp. for a period of 5 seconds. If starting (*Continued on page* 458)

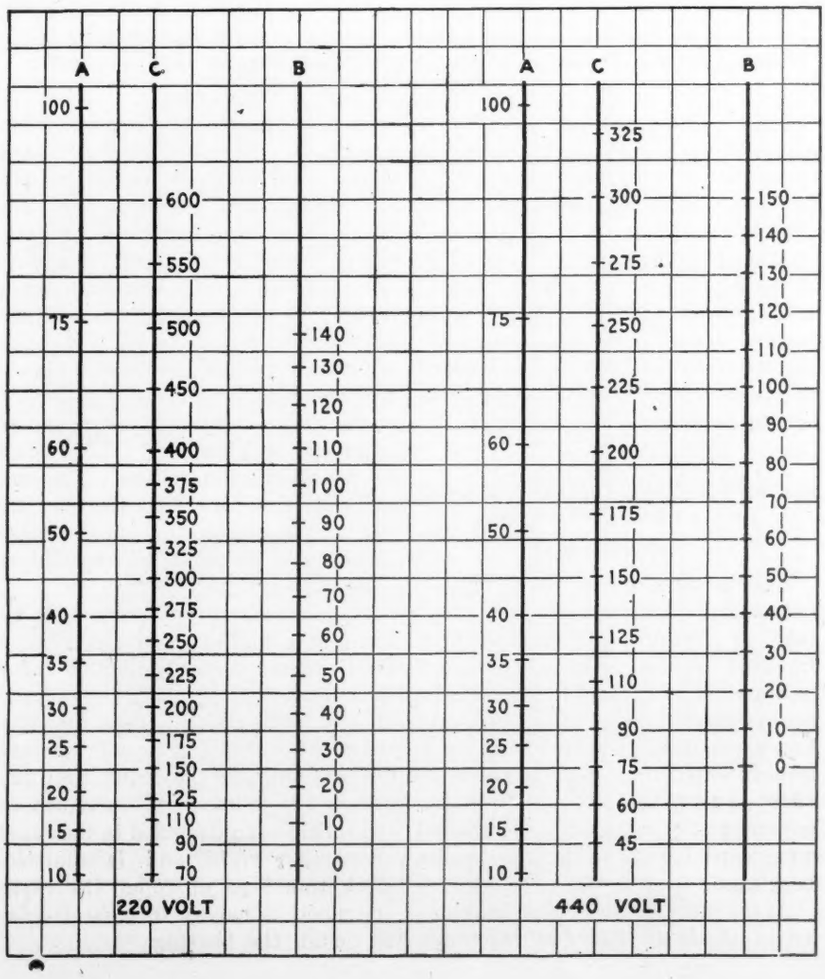


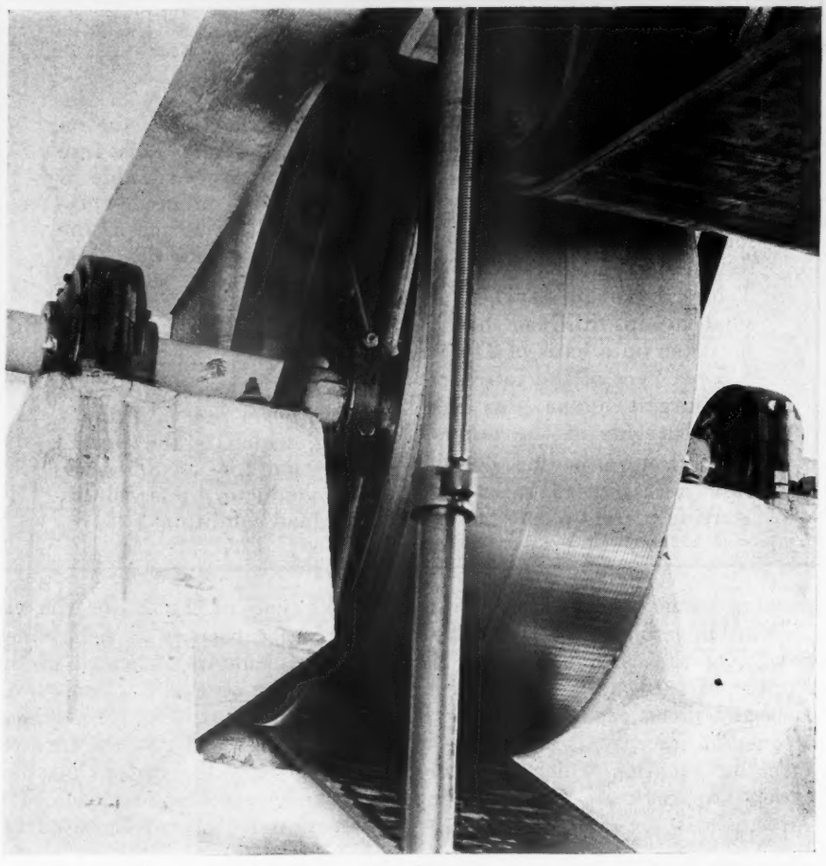
Fig. 3—Straight line diagrams for determining size of fuse or size of conductor as feeder supplying more than one induction motor.

These diagrams are based on the assumption that the starting current of the largest motor has a value of 4½ times full-load current for a period of 50 to 55 seconds when the remaining motors are carrying full load. They are determined from the following equations: F=4.5 (P'+.22P +5.5) for 220-volt, 3-phase motors, and F=2.25 (P'+.22 P+11) for 440-volt, 3-phase motors, where P'= horsepower of largest motor and P= horsepower of remaining motors. To find the size of fuse required, lay a straightedge across scales *A* and *B* so that it intersects *A* at the horsepower capacity of the largest motor in the group and *B* at the sum of the capacities of the remaining motors. The size of fuse required in the feeder is indicated on the scale *C*. To determine the size of conductor required in the feeder, take the sum of the current ratings of the motors plus 10 per cent of the current rating of the largest motor and select the conductor size from Table *A*. If the size of fuse required exceeds the Table *C* rating of the conductor, a larger conductor must be used. These curves should be used in conjunction with Fig. 2, since they do not indicate when a group motor installation lies outside the dotted line of Fig. 2 and for some combinations may indicate a smaller fuse than will properly care for the normal currents of the motors.

BY PROPERLY ALIGNING shafting and providing bearings and pulleys that are best suited to the requirements of the machines driven, a marked power saving in friction load of shafting installations can be effected. In this article the construction features of roller and ball bearings used for this purpose and some essential details of installation practice are discussed.

Ball and Roller Bearings

With Details of Their Installation on Lineshafts and When Substituted for Sleeve Bearings



The shaft for this 60-in. receiving pulley in the plant of the Menasha Printing and Carton Company, Menasha, Wis., is supported on ball bearings. The 28-in. leather belt transmits 260 horsepower

By G. A. VAN BRUNT

Managing Editor, Industrial Engineer

FOR MANY years what is ordinarily known as the plain or babbitt type of bearing was used almost exclusively to support and hold in the proper position the moving parts of machines, lineshafts and so on. Such bearings have the advantage of being fairly cheap and easy to make, and under many conditions serve reasonably well the purpose for which they are intended. On the other hand, practical experience supplemented by careful study and investigation has disclosed many inherent defects. Perhaps the most serious of these defects is the comparatively large amount of friction which is always developed between the bearing and the moving element. This is, of course, due to the fact that a large part of the area of the journal is in close contact with the bearing. The extent of this friction has been found to vary between 15 and 50 per cent of the power input consumed at the point where bearings are used, depending upon the type of installation and the number of bearings employed. It is the source of power losses which are too large to be disregarded.

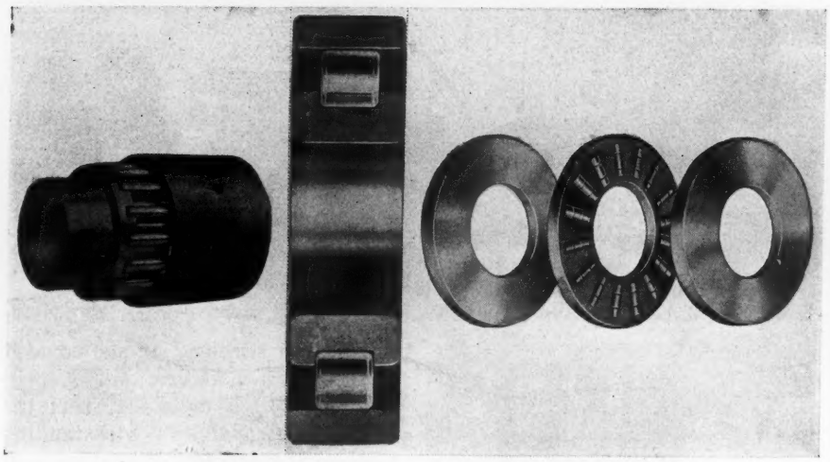
Other disadvantages connected with plain bearings are the frequent inspection which they require, the renewals which are necessary from time to time, depending on the conditions of service, and the possibility of the bearing running hot or otherwise failing, with consequent shutdowns which may be expensive. Maintenance practice when sleeve bearings are used was outlined in an article in the June issue by A. L. Gear.

Roller Bearings Differ Considerably in Design and Construction

Efforts were made years ago to reduce the friction of ordinary bearings by the use of small rollers. In 1794 bronze rollers 1 3/16 in. in diameter were used to support the heavy weather vane of a church in Lancaster, Pa., and were still functioning when they were removed in 1909. Later, in 1847, the Bavarian government railroads conducted many experiments on the use of roller bearings.

At the present time roller bearings are used on all kinds of machines, lineshafts, automobiles and trucks, and so on. They are generally used where heavy loads and comparatively low speeds are encountered. Although the designs made by the different manufacturers vary considerably, they all consist essentially of a number of rollers made from either high-carbon or alloy steel. They are accurately ground to size and highly polished, and are held in the proper position by a light cage consisting of end rings with properly spaced holes for retaining the rollers. The end rings in turn are held together by heavy rods or spacing bars. These rollers may be made either solid or hollow.

One manufacturer forms them by winding a flat strip of heavy alloy steel around a mandrel. The roller thus formed is then heat-treated and ground. The claim is made that this construction gives a certain amount of flexibility to the roller and improves the lubrication, inasmuch as the rollers are assembled in the cages alternately right and left-handed. With this type of roller the cages are made in halves, to make it easy to install the bearing.



Here are three designs of roller bearings.

The illustration at the left shows a roller bearing provided with case and sleeve. It is designed for sustaining radial loads only. The rollers of the bearing in the center are short so that it can be used interchangeably with ball bearings or when, because of space limitations or for other reasons, it is not desired to employ bearings with long rollers. At the right is shown one design of thrust roller bearing. The steel rollers are made in short sections and held in a bronze roller cage. They bear against steel plates which, like the rollers, are hardened and ground.

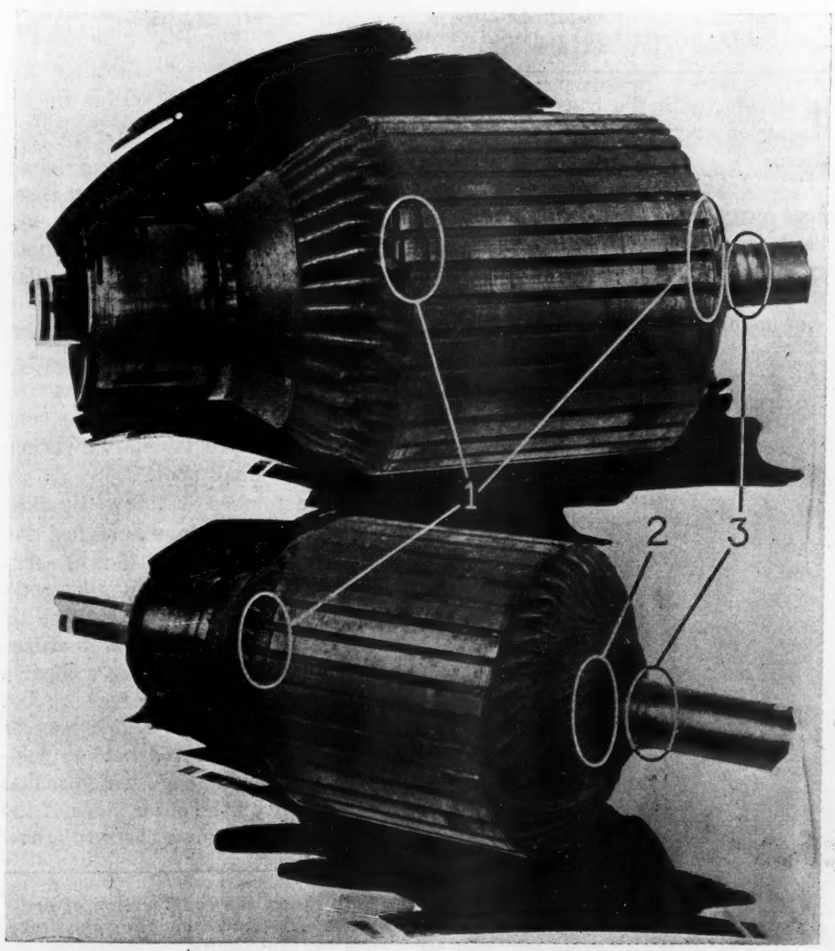
The length and diameter of the rollers vary considerably in the different makes. That is, the rollers in some bearings are comparatively long, while in others the length closely approaches the diameter of the roller.

Regardless of the type of bearing an inner and outer race must be provided for the rollers. In some designs the lineshaft or journal itself forms the inner race and rests directly on the rollers. In order that the best results may be obtained, and particularly for a long life of the bearing, it is advisable to use a cold-rolled or cold-turned shaft. Otherwise, the use of a hardened and polished sleeve, which is fitted over the shaft and forms the inner race, is recommended. These sleeves are supplied by the manufacturer of the bearing and in most cases may be set on the shaft by a press fit. With large size bearings it is usually advisable to secure the sleeve in place by dowels, keys or set screws.

In the same way the bearing housing may, if it is of sufficiently hard material and is accurately ground and finished, be made to serve as the outer race. Usually, however, a casing made of cold-rolled or hardened steel is employed. In some designs this casing is riveted to and forms an integral part of the housing. Otherwise the casing is either put in place with a press fit or a very light press fit is supplemented by dowels, keys or screws.

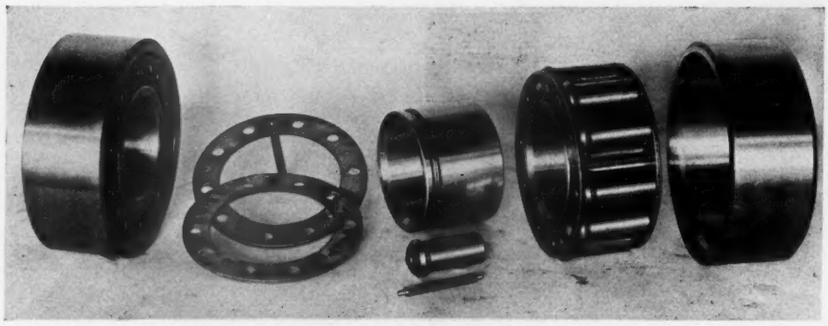
In order to prevent binding it is necessary, when installing roller bearings, to see that the shaft and the bearing line up accurately. On machine installations this means that the housings must be carefully bored or ground. For lineshafts the housings are ordinarily mounted in four-point set screw hangers or ball-and-socket pillow blocks, which permit accurate line-ups to be made. Under no circumstances should the roller unit be crowded laterally, either through the construction of the bearings or casings or the method of installation.

The roller bearings described above are not designed for taking end thrust. In one bearing, however, which is designed to take both radial and thrust loads the rollers have a flange at one end. These flanges fit into corresponding grooves in the inner and outer races and take the thrust loads. The radial load is carried by the bodies of the rollers, as in the other designs. With the ordinary roller bearing, when



Some common troubles occurring on motors and generators equipped with plain bearings.

Unless detected by frequent testing of the air gaps the bearing will in time wear down enough to allow the armature to strike the field poles and produce the scoring shown at *1*. Burning of the insulation, as at *2*, may result from bearings running hot or from shorts or grounds caused by oil working out of the bearing onto the windings. Under the best of conditions some wear, *3*, takes place on the shaft when plain bearings are used. Dirt or abrasive matter in the bearing will greatly increase the amount of wear and may cause serious scoring.



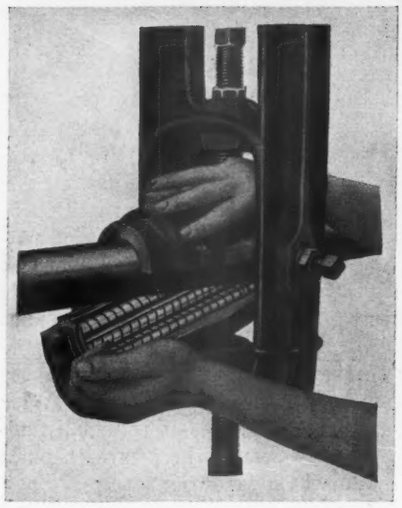
This roller bearing is designed for both radial and thrust loads.

The assembled bearing is shown at the extreme left. The other illustrations show the parts which comprise the complete bearing. It will be noted that the rollers are provided at one end with a flanged head which travels in a groove cut in the inner race and bears against a shoulder in the outer race. The thrust load is divided among the heads of all of the rollers while the radial load is carried by the bodies of the rollers in the lower portion or load zone of the bearing.

thrust loads or lateral movements are encountered, some means must be provided for controlling them. Thrust collars are generally satisfactory for ordinary loads, but ball or roller thrust bearings should be used for heavy thrust loads or where the speed is high.

Ball and Roller Bearings Require Little Attention Beyond Lubrication

One of the advantages accruing from the use of either roller or ball bearings is the comparatively small amount of attention they require. After they are installed, assuming that this has been done properly, it is only necessary to lubricate them three or four times a year. The housings are provided with reservoirs of sufficient capacity to hold several months' supply of lubricant. Although the frictional resistance of roller and ball bearings is much lower than that of plain bearings, careful attention must be paid to the selection of the lubricants used, inasmuch as the maximum usefulness of these bearings is obtained only so long as the rollers or balls remain in perfect condition. Lubrication is necessary mainly to prevent skidding or sliding, with the consequent flattening or scoring of the curved surfaces.



This split roller bearing for use on line shafts is easily installed or removed for inspection or repairs.

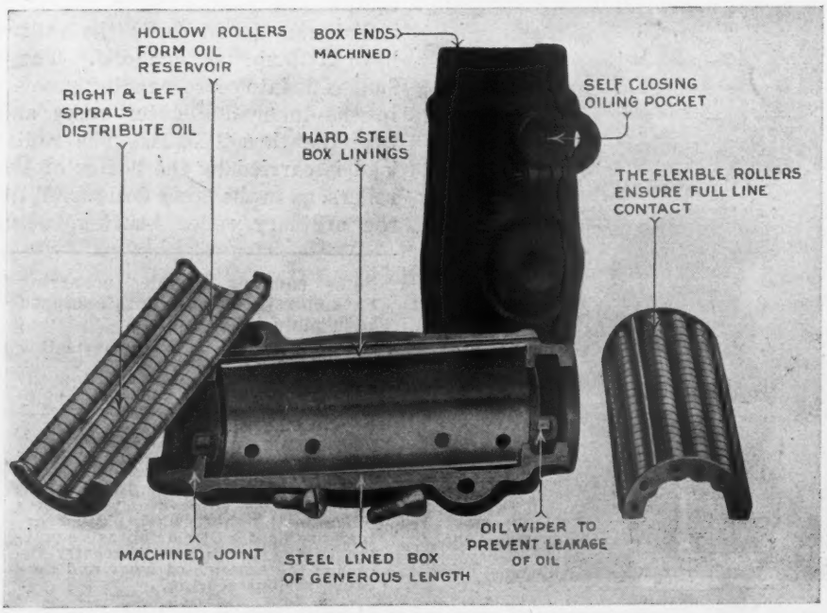
The lubricant also conducts any heat away from the bearing and protects the parts from corrosion. In general, the lubricant should possess sufficient body to accelerate rolling, but not be viscous enough to retard it or cause sliding. It should also be free from moisture, or any tendency to absorb moisture from the air, and be capable of withstanding a reasonable amount of heat without breaking down. Finally, it should not contain any acids or other substances which can cause corrosion or etching of the parts.

In practice a good grade of machine oil or a lubricant of the nature of a light cup grease are generally used. The frequency with which the bearings should be lubricated depends somewhat on the conditions of service, but as a rule it should be done at least every four months. In addition, it is a good plan to wash the bearings out with kerosene once every year and thus remove all dirt and grit, together with the old lubricant.

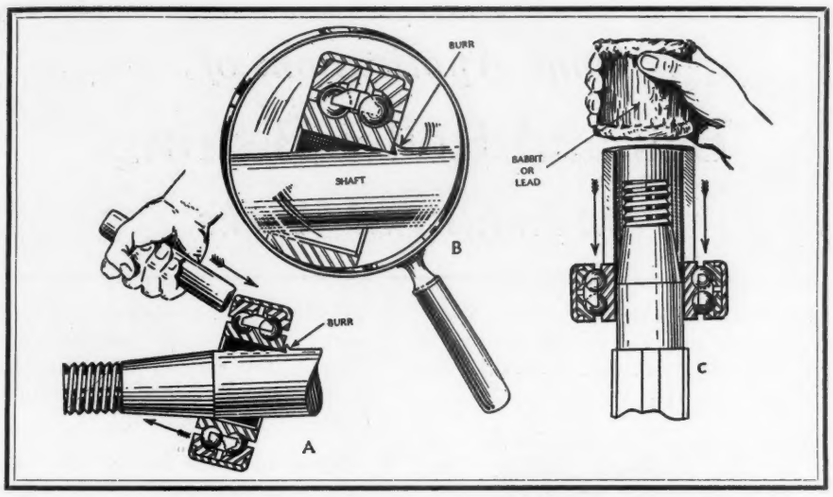
Design of Ball Bearings in General Use

Ball bearings are distinguished from roller bearings by the fact that, as the name implies, the load is carried on one or more rows of steel balls instead of rollers. The roller is a line contact while the other is often referred to as a point contact, although this is not strictly true, inasmuch as the races are ground to such a shape that the balls make contact over an appreciable area, rather than at one small spot.

A large number of different makes of radial ball bearings designed for various kinds and conditions of service are on the market, and while these vary considerably in some of their details, the essential features are similar. Briefly, they comprise an inner and an outer race, and a number of steel balls which may or may not be spaced and held in position by a circular cage which makes contact only on the outer sides of the balls and thus allows them to travel


HOLLOW ROLLERS FORM OIL RESERVOIR
BOX ENDS MACHINED
RIGHT & LEFT SPIRALS DISTRIBUTE OIL
SELF CLOSING OILING POCKET
HARD STEEL BOX LININGS
THE FLEXIBLE ROLLERS ENSURE FULL LINE CONTACT
MACHINED JOINT
STEEL LINED BOX OF GENEROUS LENGTH
OIL WIPER TO PREVENT LEAKAGE OF OIL

This shows the construction of one make of roller bearing designed for use on line shafts.

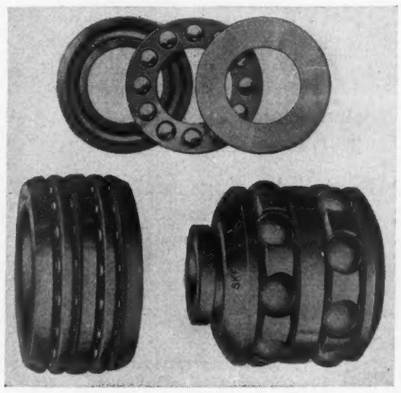


The wrong way and the right way of putting ball bearings on a shaft.

A Pounding on the outer race at one point is liable to distort or otherwise injure the bearing and in addition tends to force it on crooked and score or form burrs on the shaft. *B* This shows the burr raised when a ball bearing is improperly forced over a shaft. *C* Ball bearings may be installed without injury either to bearing or shaft by pounding on a brass tube which is large enough to slip over the shaft and bear against the inner race.

freely in the grooves which are ground in the ring-shaped races. The inner race is forced over the shaft, while the outer race is supported in the bearing housing, so that the load is carried on the steel balls placed between the two races. In at least the better grades of ball bearings the races and balls are made of high-quality alloy steel, carefully hardened and ground to very close limits. In addition the balls are polished to a mirror-like surface.

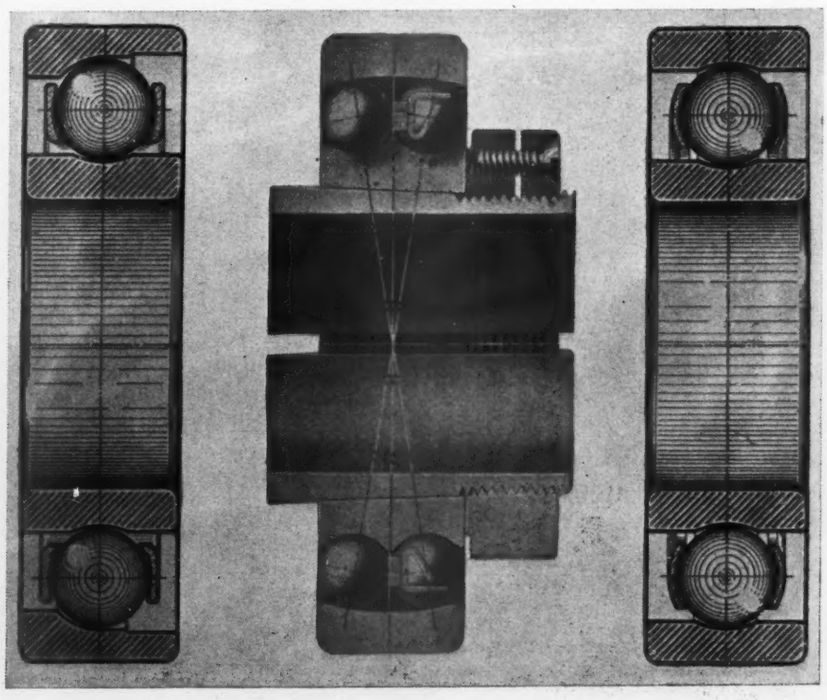
Radial ball bearings are of two general types, the closed and the open. In the closed type the races, balls and ball cage are assembled at the factory and the construction is such that the bearing cannot be taken apart without cutting the rivets which hold the two sides of the ball cage together, or distorting the cage so as to release some of the balls. In the open type, however, the three units, inner and outer races and ball cage, are easily separable without any manipulation.



Thrust ball bearings look like this.

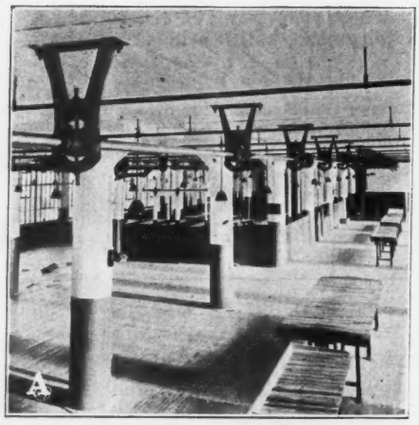
Among the more noticeable variations in the designs of the radial ball bearings put out by the different manufacturers are the shape and depth of the grooves in the races. In some bearings these are very shallow, while in others they are comparatively deep. Again, the ordinary type of bearing in which the balls travel in grooves cut in the inner and outer races requires careful aligning of the shaft and housing in order to prevent binding or distortion of the bearing. A self-aligning feature is obtained in one type of bearing by using two rows of balls and grinding the inner surface of the outer race in the form of a sphere, whose center is at the center of rotation of the bearing. The balls rotate on this spherical surface and may thus be deflected in any direction, so as to avoid cramping or wedging due to misalignment or bending of the shaft.

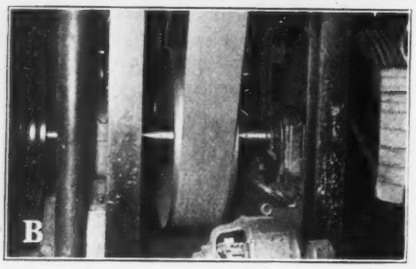
The types of bearings described above are usually designed only for withstanding radial loads, and although most of them are capable of resisting a thrust load in at least one direction, the amount of thrust which can be sustained varies with the make of the bearing and ranges from 10 to 200 per cent of the radial load rating. Before subjecting a

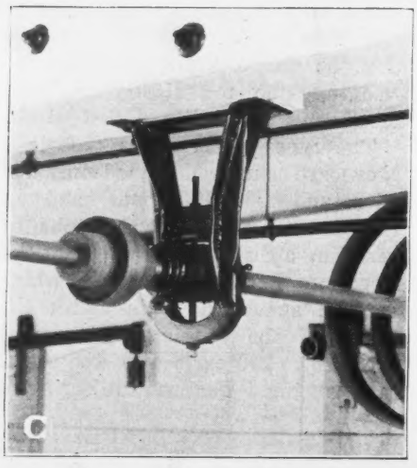


These are sectional views of ball bearings in general use.

The bearing shown at the left is of the open type. As shown the balls travel in a shallow groove ground in the inner race. One shoulder of the outer race is ground away so that it can be withdrawn sideways and the bearing quickly disassembled. The closed type ball bearing is shown at the right. These bearings are assembled at the factory and cannot be taken apart without cutting the rivets which are employed in some designs to hold the two halves of the cage together, or distorting the cage so as to release some of the balls. A self-aligning ball bearing equipped with adapters for lineshaft use is shown in the center illustration. Two rows of balls are employed and travel in grooves ground in the inner race. The outer race is ground in the form of a sphere whose center is at the center of rotation of the bearing. The balls and inner race rotate within the spherical surface at any angle and since the inner race tilts with the shaft misalignment or bending of the shaft is taken care of automatically.







Some Applications of
Ball and Roller Bearings
in Industrial Works

A—An installation of roller bearing hangers for lineshafts in the plant of Scott and Williams, Laconia, N. H.

B—The main jackshaft in the mill of the Hubbard Milling Company, Mankato, Minn., is equipped with ball bearings. This shaft is 8 7/16 in. in diameter.

C—Roller bearings support the lineshafts of the Silver Lake Company, Watertown, Mass.

D—Ball bearings make it possible for one 5-hp. motor to operate 54 knitting machines in the plant of Tonner & Moyer, Landsdale, Pa.

E—Little power is wasted in turning the lineshafts in the plant of the Menasha Printing and Carton Company, Menasha, Wis. This is one of many shafts which are supported on ball bearings.

F—The conveyors and mixing machines on the fourth floor of Sears, Roebuck and Company's paint factory are driven from lineshafts equipped with ball bearings and ball bearing clutch pulleys. Note the sprocket drives.

G—Roller bearings mean small friction losses and maintenance charges for this lineshaft in the shops of the Walker Vehicle Company, Chicago, Ill.

H—Screw machine floor of the Chicago Nut Company. All of the line- and counter-shafts turn on ball bearings.

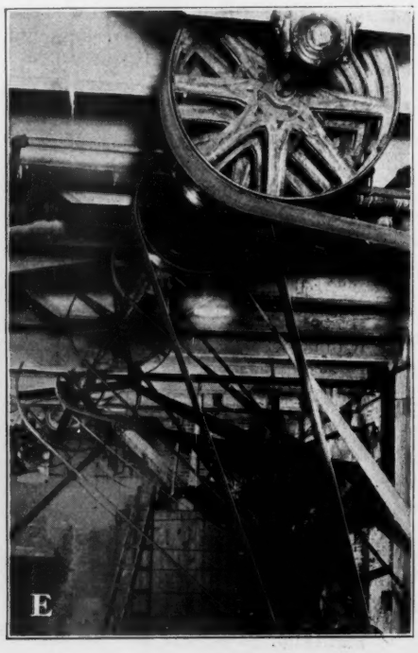
I—Ball bearings on the lineshafts of the Hudson Motor Car Company, Detroit, Mich., help to reduce the friction power losses.

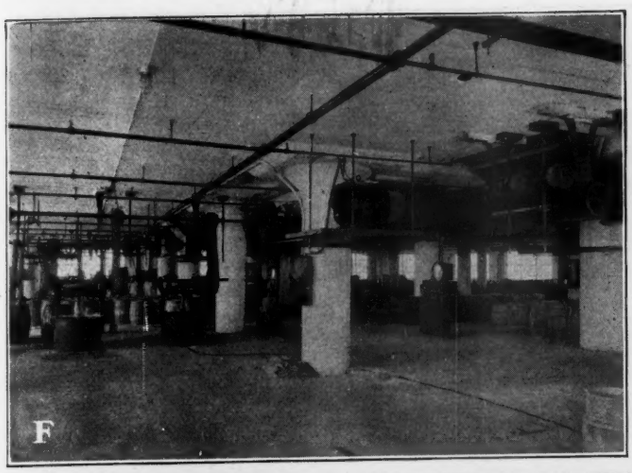
J—Another view of the shops of the Walker Vehicle Company, Chicago, Ill. This lineshaft turns on roller bearings.

K—Polishing room at the Gustave Lidseen plant, Chicago, Ill. All of the lathes and fans are driven through ball-bearing loose drives.

L—View in punch press room of this plant. Here 21 punch presses are driven through ball-bearing all loose drives and ball-bearing friction clutches.

M—Lineshaft roller bearings in plant of Goodyear Tire and Rubber Company, Los Angeles, Calif.

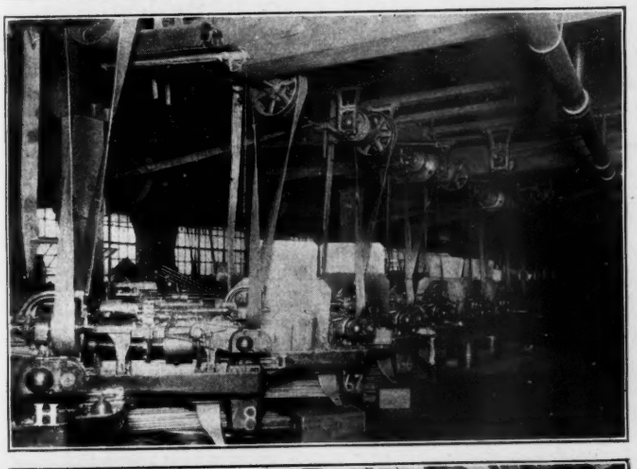



F

J

G

K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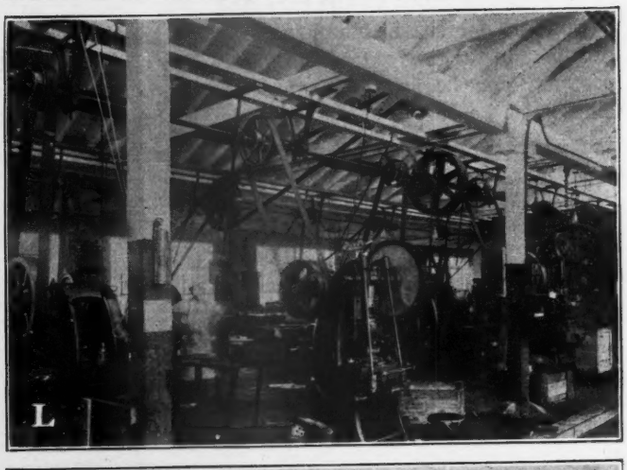
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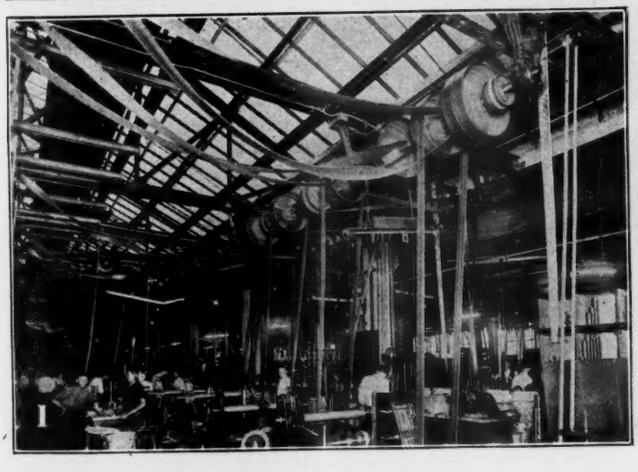
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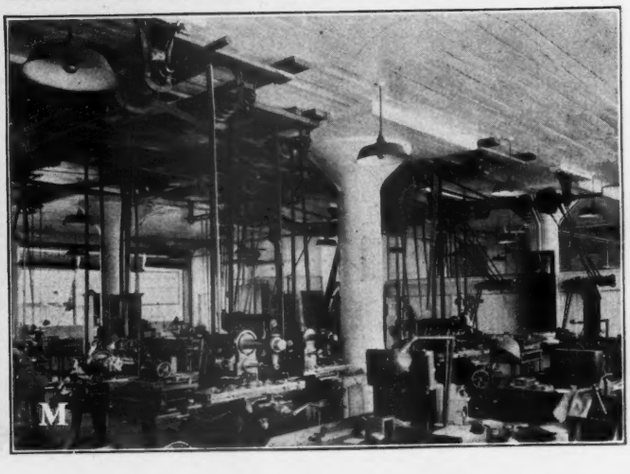
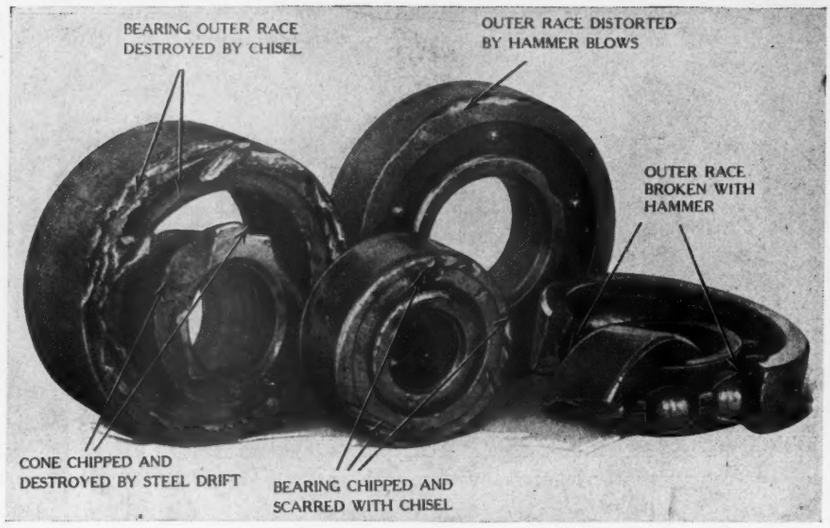

M

Ball bearings are not designed to stand the rough treatment which these bearings received.


BEARING OUTER RACE DESTROYED BY CHISEL
OUTER RACE DISTORTED BY HAMMER BLOWS
OUTER RACE BROKEN WITH HAMMER
CONE CHIPPED AND DESTROYED BY STEEL DRIFT
BEARING CHIPPED AND SCARRED WITH CHISEL

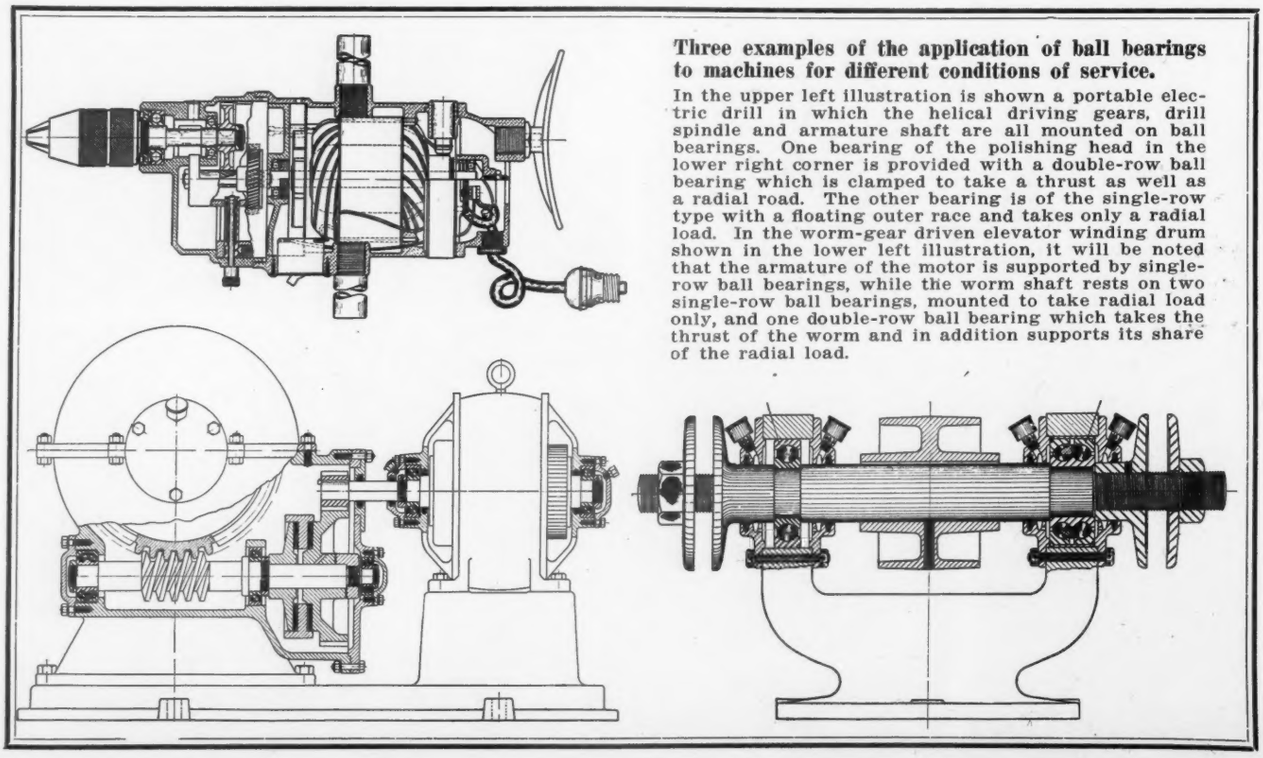
ball bearing to a thrust load of any consequence, the recommendation of the manufacturer should be obtained. When heavy thrust loads are encountered, provision must usually be made for taking care of them. Thrust ball bearings consist essentially of two or more flat races, usually with grooves ground in the faces, between which are mounted a number of balls held in a suitable cage or retainer, the exact design of which varies with the different manufacturers.

Ball bearings are also obtainable which combine in one unit the essential features of both the radial and the thrust type of bearing and thus can be used in places where it would otherwise be necessary to use two separate bearings, one radial and one thrust bearing, to take care of the load.

In the installation of ball bearings care must be taken to insure securing the conditions which are necessary for obtaining the most satisfactory results. By improper mounting or handling it is easily possible to render useless much of the care and expense to which the manufacturer has gone in turning out a high-grade product. In the first place, precaution must be taken to see that the bearing is clean and particularly that there is no grit or abrasive material on the balls or races. For this reason it is advisable to leave bearings in their original packages until it is desired to inspect or install them. They may then be washed in kerosene, rinsed in clean kerosene and blown out with compressed air.

The inner race should be a light press or drive fit on the shaft and it is advisable to lock or clamp it in place to prevent endwise movement. For lineshaft applications an adapter is generally used whereby the bearings are gripped on the shaft by means of a split tapered sleeve between it and the inner race, which is tapered to correspond to the taper on the sleeve. The sleeve is drawn up and held securely in place by a locknut and set screw.

When forcing the inner race over a shaft, serious damage may be done by pounding on the bearing face or using a cold chisel or steel drift. In the same way, applying excessive pressure on the outer race, or pounding it with even a babbitt or other soft-faced hammer is not conducive to the best results. Although no apparent injury to the bearing may result, it is liable to be forced on crooked, scoring the shaft and destroying the fine alignment which is necessary for the best results. The



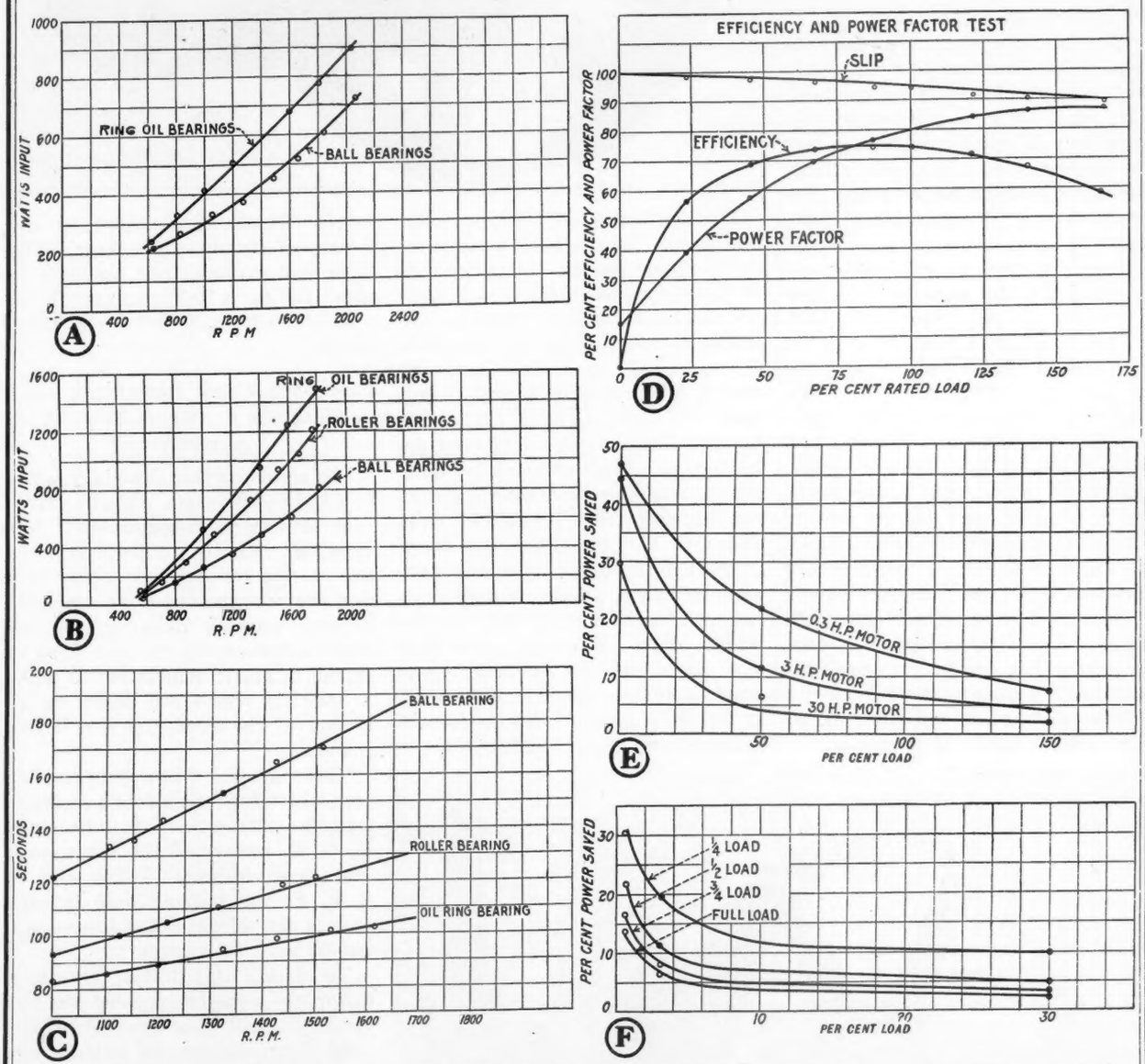
Three examples of the application of ball bearings to machines for different conditions of service.

In the upper left illustration is shown a portable electric drill in which the helical driving gears, drill spindle and armature shaft are all mounted on ball bearings. One bearing of the polishing head in the lower right corner is provided with a double-row ball bearing which is clamped to take a thrust as well as a radial road. The other bearing is of the single-row type with a floating outer race and takes only a radial load. In the worm-gear driven elevator winding drum shown in the lower left illustration, it will be noted that the armature of the motor is supported by single-row ball bearings, while the worm shaft rests on two single-row ball bearings, mounted to take radial load only, and one double-row ball bearing which takes the thrust of the worm and in addition supports its share of the radial load.

proper way to apply the bearing is to force it on in a press or drive it on by pounding on a piece of brass tubing which is slipped over, and is slightly larger than, the shaft and thus bears only against the inner race. Likewise, when removing a bearing from a shaft, care must be taken not to distort or mar it or the shaft.

There is some difference in practice in regard to the proper fit of the outer race in the housing. With the closed type of ball bearing the race is usually not held rigidly in the housing, but is made a sucking fit, so as to allow a slight creeping or rotation of the race when the bearing is in operation, thus insuring, it is contended, a more perfect distribution of the load over the whole track of

Comparative Tests on Motors Equipped With Plain, Roller and Ball Bearings



A. Two motors which were alike except that one was equipped with ring oil bearings and the other with ball bearings, were driven by a third motor. The watt input represents the windage and friction losses of both driven and driving motor, but since the latter was used in both cases the difference in the losses represents the saving in power, from decreased friction, required to drive a ball bearing motor as compared to a ring oil bearing motor.

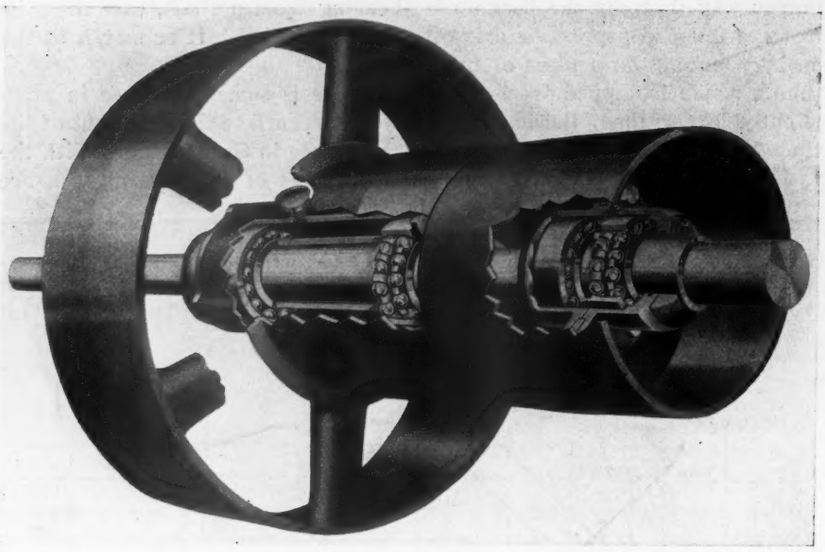
B. This shows the windage and friction losses on three motors of similar rating and identical except for the bearings. The losses of the driving motor have been deducted from the watt input, although the losses shown include those occasioned by the driving belt.

C. These curves were obtained by determining the number of seconds the armatures of the three motors used in the previous test rotated after the power was cut off.

D. According to these efficiency and power factor curves, which were obtained from tests on a 1-hp. ball-bearing induction motor, the power factor exceeds 80 per cent at all loads in excess of 90 per cent of the normal rating. The efficiency is highest at about 85 per cent of the rated load, although it reaches 75 per cent or higher with any load between 63 per cent and 113 per cent of the rated load.

E. The percentage of power saved at various loads with motors of 0.3 hp., 3 hp. and 30 hp., respectively, through the use of ball bearings, as compared with plain bearings, is shown by these curves.

F. The saving in power which may be expected with any motor up to 30 hp. at any per cent of load, when ball bearings instead of plain bearings are used. These curves were plotted from the results shown in *E.* (The above data were taken from a bulletin issued by S. K. F. Industries, Inc.)



An application of ball bearings to loose pulleys.
The large and small pulley are cast as one. The other small pulley is loose and serves as the idler. This outfit is designed to replace worn-out countershafts and is installed by slipping the pulleys over the old shaft, which is then tightened in the hanger boxes, to keep it from turning.

the outer race. For this purpose, the housing is accurately finished to a dimension a few ten-thousandths of an inch larger than the outside diameter of the bearing.

On the other hand, with the open type of ball bearing both the inner and outer races are rigidly mounted. The inner race is pressed on the shaft and the outer race pressed into its bearing, with a fit which is tight enough to prevent all movement, but of course not so tight as to cause distortion.

The lubrication of ball bearings is substantially the same as described previously for roller bearings. That is, the bearings should be oiled or packed with grease before being put in operation, using only high-grade materials which are free from acid or other deleterious substances and of the proper body. For low speeds, up to 600 r.p.m., and heavy loads, grease may be used, but for higher speeds, light mineral lubricating oil should be employed. Under ordinary circumstances the bearings should be supplied with fresh lubricant three or four times a year. On these occasions it is advisable to wash the bearings thoroughly with kerosene, to remove all of the old lubricant before adding fresh oil or grease.

The application of ball or roller bearings to lineshafts is a comparatively simple matter, but in the case of motors or machines which were not designed for such bearings the problems encountered are generally different and somewhat more involved. The following procedure outlined by J. H. Gallant of Canada Cement Company, Limited, and detailing the procedure which he found satisfactory in changing motors ranging from 10 hp. to 50 hp. from sleeve to ball bearings, will be of interest to those who may have occasion to make similar transformations. Altogether about fifty motors, which drive elevators, conveyors and other material-handling equipment, have been changed over, mainly for the purpose of eliminating the frequent and costly interruptions to service which were caused by the failure of babbitted bearings. The labor and material cost amounts to about $50 for a 10-hp. motor, $75 for a 25-hp. motor and $100 for a 50-hp. motor.

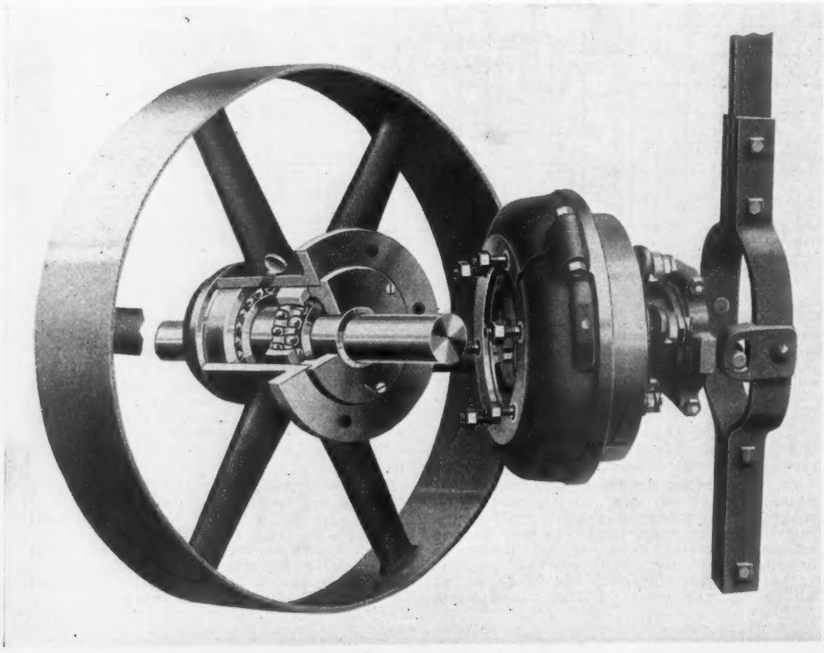
Procedure When Installing Ball Bearings on Sleeve-Bearing Motors

The accompanying drawings apply to a 10-hp., 900-r.p.m. Canadian General Electric motor which was changed recently; the dimensions are correct for that one motor only and are not intended to be used as a general working drawing, for the slight differences in the cast-iron end shields make it impossible to show a drawing which will apply to all motors of the same size and horsepower.

There are also shown drawings for caps which have been found satisfactory for fitting with ball bearings C. G. E. motors of the horsepower and speed indicated. The size of S. K. F. ball bearing used in each case is also given in the accompanying table.

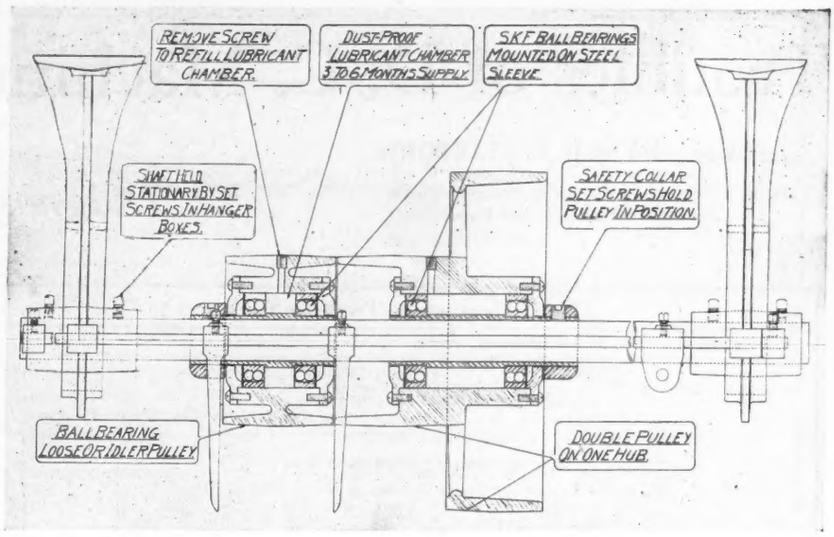
To change this 10-hp., 900-r.p.m. motor, the material required was two S. K. F. ball bearings, series No. 1309, four castings off pattern No. L-656, six ⅜-in. by 4½-in. machine bolts, two ¼-in. by ½-in. set screws, some hard babbitt and enough steel for two ½-in. thick locknuts.

After the motor is taken down the end shield is placed in the lathe and centered with the finished side, which when assembled fits against the faced side of the stator spider.



Cut-away view of ball bearing friction clutch pulley.

Diagrammatic view of ball bearing loose pulleys mounted on stationary shaft.

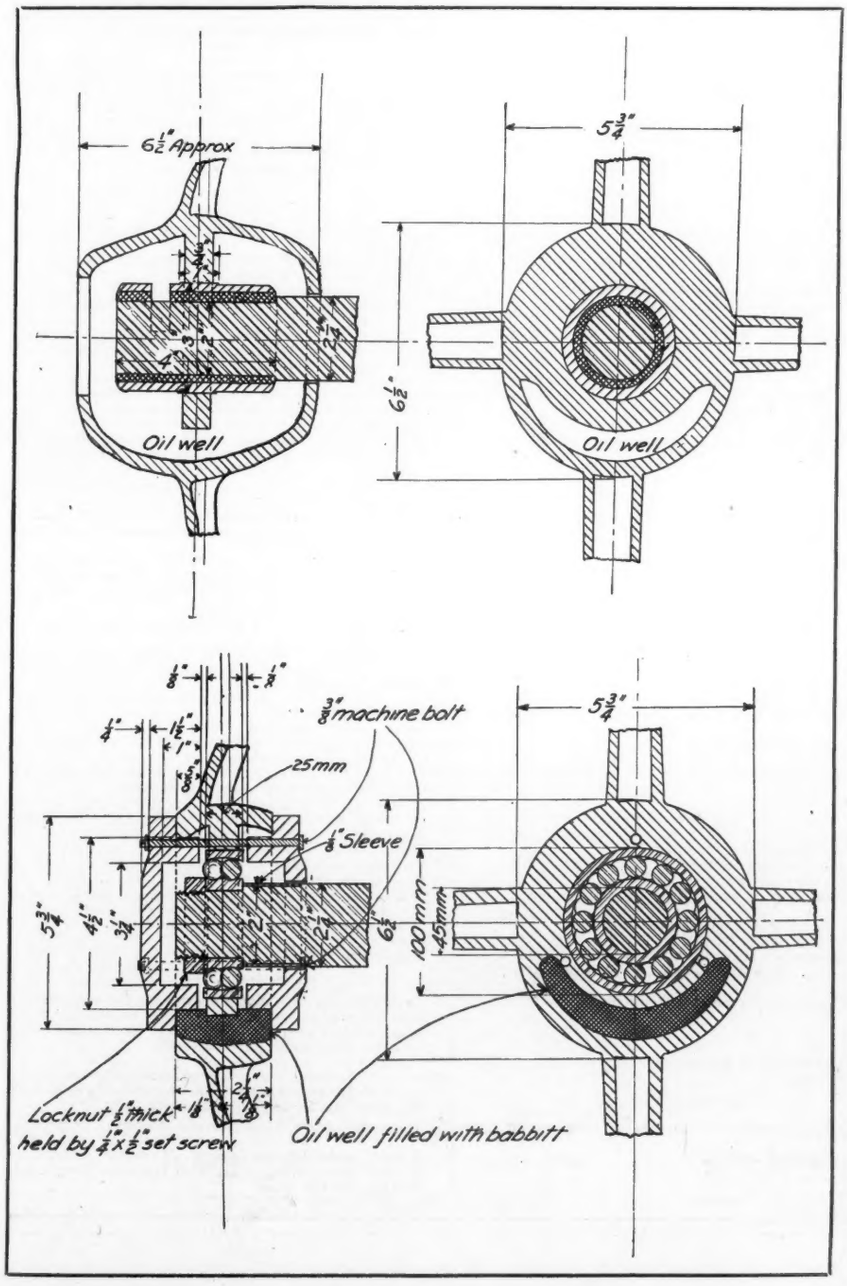

REMOVE SCREW TO REFILL LUBRICANT CHAMBER.
DUST-PROOF LUBRICANT CHAMBER 3 TO 6 MONTHS SUPPLY.
S.K.F. BALL BEARINGS MOUNTED ON STEEL SLEEVE.
SHAFT HELD STATIONARY BY SET SCREWS IN HANGER BOXES.
SAFETY COLLAR SET SCREWS HOLD PULLEY IN POSITION.
BALL BEARING LOOSE OR IDLER PULLEY
DOUBLE PULLEY ON ONE HUB.

against the face plate of the lathe. Both ends of the bearing housing are then cut off. For 10-hp. motors the housing is cut 1⅛ in. from the center line of the finished part, inside the housing into which the babbitted bearing fits, leaving a housing 2¼ in. long, as shown in the drawing.

The length to cut the housing is determined by the thickness of the ball bearing and the end caps; ⅛ in. is generally allowed on each side between the ball bearing and the caps for lateral adjustment, so that there will be no binding of the balls against the spherically-shaped outside race, due to side magnetic pull. The finished part inside the housing is then bored to such a size that the ball bearing can just be pushed in by hand, what is called a push fit. Next both ends of the housing are machined to fit the caps. This finishes the lathe work on the end shields. The end caps are then machined to approximately the dimensions shown in the drawing; the caps through which the shaft passes should be bored to a fine running clearance of about 0.01 in. and small grooves cut in this finished side so that grease will be drawn in by suction and will seal the bearing against dust and moisture.

The hollow oil well in the bottom of the housing has next to be filled with hard babbitt, as there is very little metal, sometimes none at all, left to support the ball bearing after the old bearing support has been bored.

This metal is also required to support the bottom of the end caps, as they have to be turned of such a size that there generally is no metal left under nearly all of the bottom half, the space (*Continued on page* 459)



Details of bearing housing of 10-hp. motor before and after installation of ball bearings.

The two upper drawings show sectional views of the plain bearings with which the motor was originally fitted. As is illustrated in the lower drawings, the ends of the housing are cut off, shortening it considerably, after which the oil well is filled with hard babbitt and the inside of the housing is bored to the proper size to receive the ball bearing. New caps are then fitted to the ends of the housing and held in place by long machine bolts. The bearing is fastened securely in position on the shaft by a locknut held by a set-screw.

Troubles of D. C. Machines—

Diagnosis and Remedies

Compiled by H. E. STAFFORD

Electrical Engineer,
Provincial Paper Mills,
Port Arthur, Ont.

Section I—Troubles Common to Generators and Motors

SYMPTOM	TROUBLE	CAUSE	REMEDY
1 Bearing too hot to touch or smoking.	*A* Bearing dry.	*A*[1] Not sufficient oil.	*A*[1] Refill with clean oil, after washing bearing with kerosene.
		A[2] Oil rings not working.	*A*[2] Same as *A*[1].
	B Bearing dirty.	*B* Dust or dirt in oil.	*B* Same as above.
	C Bearing tight.	*C* Cause *A* and *B* or particles of metal sheared off and deposited at other parts.	*C* Scrape bearing and shaft or replace bearing. (Never use ice or water on a bearing unless the machine is kept running as it is liable to spring the shaft.)
	D Oil rings not working.	*D* Rings out of slots.	*D* Replace rings, making sure no metal adheres to sides of slots. If rings stick or run slowly, bevel at either top or bottom with a fine file.
	E Bearing binding.	*E* Shaft out of true	*E* Place shaft in lathe and true, and renew bearing.
	F Bearing out of true.	*F* Too much strain on pulley.	*F* Bearing should be shimmed with thin pieces of tin as a temporary measure or replaced by a new one.
	G Loose bearing.	*G* Vibration.	*G* Tighten set screws holding bearing in journal.
2 Bearing hot but no hotter than other parts of frame.	Heat transferred from armature.	Overload.	Decrease load and increase size of machine.
3 Sparking of brushes.	*A* Brushes not diametrically opposite.	*A* Brush holder studs loose, or not set properly.	*A* Measure with a tape or count commutator segments, and adjust brushes on diametrically opposite bars.
	B Brushes not set on neutral point in relation to field.	*B* Set screw holding rocker arm may have become loose or rocker arm shifted through carelessness.	*B* Shift rocker arm and brushes ahead or in the direction of rotation for a generator, and backward or against the direction of rotation for a motor.
	C One or more brushes in contact with wrong number of commutator bars.	*C* One or more brushes thicker than others.	*C* Trim all brushes to same thickness.
	D Brushes cover too many bars.	*D* Brushes too thick for design of motor or generator.	*D* Use proper brushes or grind those in use to proper thickness.
	E Brushes out of line.	*E* Brush holders not set properly on studs.	*E* Adjust holders so that they line up properly.
	F Brushes too short.	*F* Wear.	*F* Replace with new brushes.
	G Poor contact between brush and commutator.	*G*[1] Oil and grit on commutator.	*G*[1] Clean commutator with a dry rag (never use waste).
		G[2] Flint or other hard substance in brush.	*G*[2] Sand paper the brush to remove foreign matter, keeping it the shape of the commutator.
		G[3] Brushes not trimmed properly.	*G*[3] Place a piece of sand paper under brush with smooth side on commutator and work back and forth until brush fits the commutator at all points. (Do not use emery cloth or paper.)
	H Rough commutator.	*H*[1] Vibration.	*H* If taken in time, the commutator may be trued by using a wooden block, hollowed out to the shape of the commutator and in which is placed a piece of sand paper. (Do not use emery cloth or paper). The use of a commutator stone is recommended in preference to sand paper. If commutator is too rough it should be trued in a lathe. (Clean all copper dust from commutator before putting it back in service.)
		H[2] Uneven brushes.	
		H[3] Different quality of bars.	
		H[4] Uneven ridges where brushes do not touch commutator.	
	I High commutator bars.	*I* Jam nuts and rings holding segments in place are loose.	*I* Carefully drive high bars back into place and tighten rings and jam nuts. Smooth commutator with sandpaper or stone as outlined in *H*.
	J Low bars.	*J* Rough handling or wearing away due to bars being soft or from a short-circuited coil.	*J* Loosen jam nuts and ring and lift bars even with others if possible, and true the commutator. If bars cannot be lifted commutator will have to be placed in a lathe and turned down even with low bars.
	K Loose bars.	*K* Clamping ring and jam nut loose.	*K* Tighten ring and jam nut and true commutator as outlined in *H*.
	L High mica.	*L* Copper wears faster than mica.	*L* Undercut mica below surface of bars. See that all dust is removed before putting machine back in service.
	M Weak magnetic field.	*M*[1] Open circuit in field	*M* Repair or rewind.
		M[2] Short circuit in field.	
	N Excessive current in armature.	*N* Too much load on machine.	*N** Reduce electrical load. † Reduce mechanical load.
	O Ground on machine or line.	*O* Defective insulation.	*O* Remove ground if possible or cut out the grounded coil or rewind the grounded part.
	P Short circuit in armature or on line supplied by generator.	*P* Same as above	*P* Cut out short-circuited coil and bridge the adjacent commutator bars as a temporary measure. * Remove short circuit on line. If properly fused, a short circuit on the line will blow the fuse and protect the generator.
	*Q** Voltage too high.	*Q*[1] Armature r.p.m. too high.	*Q*[1] Reduce speed of prime mover.
		Q[2] Field current too great.	*Q*[2] Cut more resistance in field circuit.
	R† Armature current of motor too great.	*R*[1] Motor overloaded.	*R*[1] Reduce mechanical load.
		R[2] Controller of wrong type for given motor.	*R*[2] Replace with proper controller having the right amount of resistance for controlling armature current.
	S Commutator bars, short circuited and mica worn or eaten away causing deep pits between bars.	*S*[1] Copper or carbon dust between bars.	*S*[1] Remove foreign matter from commutator.
		S[2] Melted solder from leads between bars.	*S*[2] Same as above.
		S[3] Insulation between brushes and holders broken down. This also causes a ground on the machine.	*S*[3] Repair insulation.
	T Open-circuited armature coils.	*T*[1] Conductor burned by short circuit.	*T*[1] Bridge the open circuit by connecting the commutator bars adjacent to the break or stagger the brushes in all brush holders where there are two or more in line, so as to cover the break. (Note below.)
		T[2] Connection at commutator bar becomes unsoldered by heat.	*T*[2] Resolder. (Note—In "Jumping" an open circuit of this kind, be careful not to short circuit a good coil as this will only aggravate the sparking, beside ruining the coil.
	U Reversed armature coil.	*U* Cross connection to wrong commutator bars.	*U* Test polarity with a compass and connect to proper bar.
	V Blow holes in frame.	*V* Improper casting.	*V* Return machine to the factory. A trouble of this kind is hard to locate; but if all other remedies have failed, this may be the cause.

*For generator only †For motor only

Section I—Troubles Common to Direct-Current Generators and Motors—Continued

SYMPTON	TROUBLE	CAUSE	REMEDY
4 Rings of fire follow the brushes around commutator.	*A* Short-circuited armature coil. *B* Open-circuited armature coil.	Same as causes *P* and *T* symptom 3.	Same as remedies *P* and *T* symptom 3.
5 Flashing or excessive arcing from brush to brush.	*A*† Excessive voltage impressed on motor.	*A*1 High voltage on line. *A*2 Motor may be built for a voltage lower than is impressed on it.	*A*1 Reduce voltage if possible. *A*2 Change motor for one to operate on higher voltage. Change setting of brushes. Motors are some times designed for two voltages.
	*B** Short circuit in generator line.	*B* Usual short-circuit causes.	*B* Remove the cause. If line is properly protected fuses will blow.
6 Singing of brushes	*A* Brush pressure too great. *B* Brushec too hard.	*A* Brush holders not properly adjusted.	*A* Remove part of the tension of the brush holder springs. (Brush pressure on commutator should equal 1½ lb. per square inch.) *B* Replace brushes with ones of softer material. The use of graphite brushes will eliminate singing. Note—A small quantity of vaseline on a clean cloth rubbed on the commutator will help reduce singing. The commutator should be wiped dry immediately after using.
7 Chattering of brushes.	*A* High bars. *B* Low bars. *C* High mica. *D* Loose bars.	Same as causes in symptom 3.	Same as remedies *I*, *J*, *K* and *L*, symptom 3.
	E Brushes set at improper angle for direction of rotation.	*E* Wrong direction of rotation.	*E*1* Reverse angle of brush setting or change polarity of generator and reverse rotation of prime mover. (Do not cross a belt.) *E*2† Motor brushes are usually set for rotation in either direction.
	F Improper end play.	*F* Shaft collars not properly set.	*F* Reset collars and adjust end play. End play should not be less than $\frac{1}{64}$ in. or greater than $\frac{1}{32}$ in.
	G High ridges on commutator.	*G* Not enough end play.	*G* Same as above. Remove ridges by turning in a lathe or by means of a commutator stone.
8 Blackening of commutator at certain spots.	*A* Short circuit in armature. *B* Open circuit in armature.	Same as *P* and *T* symptom 3.	Same as *P* and *T* symptom 3.
9 Armature hot all over.	*A* Overload on motor or generator.	*A* Overload.	*A** Reduce electrical load. † Reduce mechanical load.
	B Moisture in coils.	*B* Operating in a damp place.	*B* Dry out by running with light load or bake in an oven.
	C Armature out of center between poles.	*C* Bearing worn on one side.	*C* Replace bearing or shim the one in use.
	D Eddy currents in armature core.	*D* Faulty construction.	*D* Rebuild core of thinner sheets or laminations (seldom encountered.)
10 Armature hot in spots and cool in others.	*A* Short-circuited coil or coils. *B* Open-circuited coil or coils.	*A* and *B* same as *P* and *T* symptom 3.	*A* and *B* same as *P* and *T* symptom 3.
	C Reversed polarity of armature coils.	*C* Cross connection.	*C* Reconnect reversed coils to proper bars.
11 Armature issues a pounding sound.	Armature striking or rubbing pole pieces.	Bearing worn on one side.	Shim the bearing or replace with new one.
12 Armature issues a loud humming sound	Path of magnetism spread out too much.	Pole shoes too flat.	Chamfer pole pieces so as to reduce the area of the path of the magnetic flux. Reduce the magnetic field. This trouble will not be encountered in a modern machine.
13 Series field coils hot.	*A* Excessive current.	*A* Coils wound with too much wire or too small wire.	*A* Increase size of wire, reduce winding or reduce current.
	B Moisture in coils.	*B* Dampness.	*B* Bake coils in an oven or by passing a small current through them.
	C Speed too low.	*C** Prime-mover speed too low.	*C** Increase speed of prime-mover. Increase size of driving pulley. Decrease size of driven pulley.
		C† Too much resistance in series with armature.	*C*† Cut out resistance.
	D Partial short circuit in one or more field coils.	*D* Moisture in coils.	*D* Dry out coils and rewind if necessary.
	E Brushes not on neutral point.	*E* Shifted through accident or not set properly.	*E* Shift rocker arm until minimum sparking takes place.
	F Overload.	*F* Overload.	*F* Reduce load.
14 Shunt field coils hot.	*A* Excessive current.	*A*1 Partial short circuit. *A*2 Not enough turns in winding.	*A*1 Same as remedy *D*, symptom 13. *A*2 Add more turns or wind with smaller size wire or add external resistance.
		*A*3 Voltage too high.	*A*3* Decrease voltage by decreasing the speed † Same as *A*2 symptom 14.
		*A*4 Brushes not on neutral point. *A*5 Moisture in coils. *A*6 Overload.	*A*4 Same as remedy *E* symptom 13. *A*5 Same as remedy *D*, symptom 13 *A*6 Remove part of load.
15 Pole pieces hotter than field coils.	*A* Eddy currents.	*A* Faulty construction.	*A* Replace with laminated poles if necessary.
	B Current through fields fluctuating.	*B* Load unstable.	*B* Provide field circuit with automatic regulator.

*For generator only †For motor only

Section II—Direct-Current Motor Troubles

SYMPTON	TROUBLE	CAUSE	REMEDY
16 Series motor runs away.	Armature current too great.	It is the nature of a series motor to accelerate speed if the load is decreased or if a belt comes off.	*A* Series motors should be provided with a regulator to control the field current whether operating on a constant-current or a constant-potential circuit. When operating on a constant-current circuit a rheostat connected in shunt with the armature will provide a remedy. (Do not shunt the field with the rheostat as this tends to increase the speed.)
17 Shunt motor runs too fast.	*A* Field too weak.	*A* Rheostat not properly adjusted.	*A*1 Strengthen field by cutting out field resistance. *A*2 Increase resistance of armature by cutting in the armature rheostat.
	B Voltage too high.	*B* Generator voltage too high.	*B* Reduce generator voltage or insert a resistance in series with the armature.
18 Shunt motor runs too slow.	*A* Motor overloaded.	*A* Motor overloaded.	*A* Reduce load or increase size of motor.

Section II—Direct-Current Motor Troubles, Their Causes and Remedies

Continued from previous page

SYMPTOM	TROUBLE	CAUSE	REMEDY
	B Short circuit in armature.	*B* Insulation broken down in slots or where leads cross each other.	*B* Trace the trouble and repair if possible, or cut out damaged coil by "Jumping" or connecting bars adjacent to the short-circuited coil as a temporary measure, or rewind armature (a short-circuited coil is hotter than its neighbors).
	C Armature rubbing pole faces.	*C* Bearing worn on one side.	*C* Replace bearing and line up air gap to equal thickness on all sides.
	D Friction.	*D* Bearings too tight.	*D* Remove bearings and scrape until they turn easily on the shaft.
	E Voltage too low.	*E*1 Line voltage too low.	*E*1 Increase voltage by increasing speed of generator or by cutting resistance out of generator field circuit.
		*E*2 Too much resistance in armature circuit of motor.	*E*2 Cut resistance out of armature circuit or increase resistance of field circuit. (The action of a rheostat in the armature circuit is just the opposite to that of one in the field circuit of a shunt, series or compound-wound motor.)
19 Motor fails to start.	*A* Load too great.	*A* Load too great.	*A* Disconnect load to see if motor starts light.
	B Friction.	*B* Bearing too tight.	*B* Scrape bearing and see if it turns easily on the shaft.
	C Fuse blown.	*C* Overload or short circuit.	*C* Replace fuse and try again.
	D Open circuit in line.	*D* Wires broken or disconnected.	*D* Examine line and connections and repair if this is the trouble. Test line to motor terminals with a magneto.
	E Open circuit in fields or field connections.	*E* Rough usage or original short circuit which may have burned a coil or connection.	*E* Examine field connections and test with a magneto or voltmeter and if coil is open rewind.
	F Open circuit in armature.	*F* Same as above.	*F* Test out adjacent commutator bars and locate the trouble. Bridge the gap as a temporary measure. Rewind coil or whole armature. (Note—The motor may show a tendency to run if brushes do not rest on open-circuited bar.)
	G Short circuit in fields.	*G* Dampness or defective insulation.	*G* Bake if former, rewind if latter. (Note—Where there are more than two field coils, the motor may show a tendency to start, but will not run properly with load. If motor is bi-polar it will not start.)
	H Short circuit in armature.	*H* Carbon dust between adjacent bars. Insulation of coils broken down.	*H* Clean commutator. The presence of this trouble will be denoted by flashing of brushes or by heating of one or more coils. Rewind if insulation is gone.
	I Brushes not in contact with commutator.	*I* Brushes fit too tightly in holders or holders loose.	*I* Adjust brush so that it works easily in holder and tighten holder in its proper place.
	J Poor commutation.	*J* Brushes not set on neutral point.	*J* Move rocker into neutral position.
20 Motor runs backward.	Reversed connection.	Reversed connection.	*A* On series motor reverse either field or armature. *B* On shunt motor reverse field only. *C* On compound-wound motor reverse both fields.

Section III—Direct-Current Generator Troubles With Their Causes and Remedies

SYMPTON	TROUBLE	CAUSE	REMEDY
21 Generator fails to build up.	*A* Residual magnetism destroyed.	*A* Residual magnetism lost through non-use.	*A* Charge fields with another generator or with a battery of dry cells, making sure the fields are connected for proper polarity.
	B Residual magnetism reversed.	*B*1 Reversed current through field coils.	*B*1 Connect fields for proper polarity, run machine above rated speed, short circuit the armature at the brushes, or tap the poles with a hammer. Usually any one of the above methods will cause a generator to build up. If however the above methods fail, the method outlined in "*A*" 21 will have to be resorted to. The polarity should be tested with a compass both before and after.
		*B*2 Earth's magnetism.	*B*2 Same as above.
		*B*3 Proximity of another generator.	*B*3 Same as above. Move one generator to another location or connect them so they will not affect each other.
		*B*4 Brushes shifted so that commutation is in opposite direction.	*B*4 Shift brushes in the direction of rotation or back and forth until generator builds up.
	C Short circuit in armature.	*C* Same as for motor cause "*H*" sympton 19.	*C* Same as for motor remedy "*H*" symptom 19.
	D Open circuit in armature.	*D* Same as cause "*F*" symptom 19.	*D* Same as remedy "*F*" symptom 19.
	E Short circuit in field.	*E* Same as cause "*G*" symptom 19.	*E* Same as remedy "*G*" symptom 19.
	F Open circuit in field.	*F* Same as cause "*E*" symptom 19.	*F* Same as remedy "*E*" symptom 19.
	G Short circuit in external circuit.	*G* Lamp socket, motor or line short-circuited.	*G* Search for trouble by sectionalizing the line, and remove the cause. In a case of this kind, the generator will usually try to build up and the commutator and brushes will flash. If properly protected by fuses, the machine will clear itself from the line. (Note—If the resistance or short circuit occurs on a series generator it will not build up.)
	H Fields opposed to each other.	*H*1 Field coils of either a shunt or series generator connected for the same polarity.	*H*1 Change connections between field coils and test with a compass for opposite polarity of adjacent coils. When adjacent coils show opposite polarity, the generator should build up if this is the trouble.
		*H*2 Shunt and series fields of compound-wound generator connected for proper polarity individually but connections of generator made so that they oppose or buck each other.	*H*2 Change polarity of either field but don't change connections of both as the same trouble will occur again.
	I Generator running backward.	*I* Prime-mover travelling in wrong direction.	*I* Reverse direction of rotation of prime mover or change the polarity of generator by changing the connections of the field of a shunt or series machine or one field only of a compound-wound generator. Never cross the belt unless absolutely necessary.
22 Voltage too high.	*A* Speed of generator too great.	*A* Speed of prime mover too great.	*A* Reduce speed of prime mover and adjust governor so that the speed remains constant at a given load.
	B Field too strong.	*B* Not enough resistance in series with field.	*B* Cut more resistanee in series with the field by means of a rheostat.
23 Voltage too low.	*A* Speed of generator not great enough.	*A* Speed of prime mover too low.	*A* Increase speed of prime mover, increase size of driving pulley or reduce size of driven pulley.
	B Field too weak.	*B* Too much resistance in series with the field.	*B* Cut out more resistance with the rheostat.
	C Load on generator too great.	*C* Too many lamps or motors on generator circuit.	*C* Reduce load.

Points That Should Be Considered When

Installing Motor Control

That Is Intended to Provide Low-Voltage Release and Low-Voltage Protection for Direct and Alternating Current Drives

CONTROL EQUIPMENT is so vital a part of a motor installation and so closely associated with the service range of the motor that the flexibility and limitations of that service must be known in order to provide a correct, safe and economical motor application. Mr. Harries outlines in this article some conditions which are often misunderstood when discussing low-voltage release and low-voltage protection for motor starters and speed regulators.

By HERBERT HARRIES
Milwaukee, Wis.

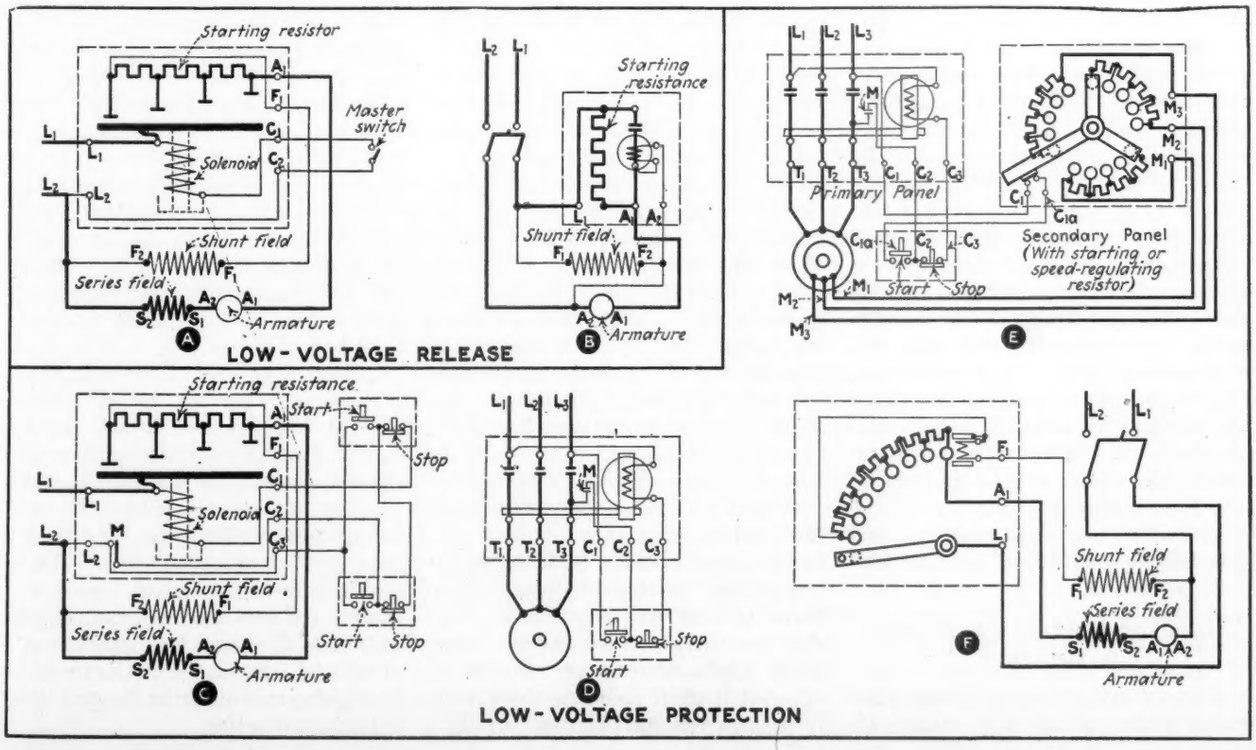
FOR a long time any device which cut an electric motor free from the line when the power failed entirely, or when the voltage fell unduly low, was known as a low-voltage release. Then the Electric Power Club, in an attempt to clarify the situation, adopted explicit definitions for the terms *low-voltage release* and *low-voltage protection.* Somewhat of a misunderstanding as to the exact meaning of these two terms, or perhaps it is simply a looseness in using them, still seems to exist, however. There is a distinct and very important difference in the idea conveyed by these two terms. The Electric Power Club defines them as follows:

Low-Voltage Release.—The effect of a device operative on the reduction or failure of voltage to cause the interruption of power to the main circuit, but not preventing the re-establishment of the main circuit on return of voltage.

Low-Voltage Protection.—The effect of a device operative on the reduction or failure of voltage to cause and maintain the interruption of power to the main circuit.

Low-voltage release (sometimes called under-voltage release) affords a certain measure of protection to the motor, but none whatever to the men working around that motor or the machinery driven by it. When used with a direct-current motor it simply prevents the motor being subjected to full line voltage with all of the starting resistor short-circuited. When used with small squirrel-cage motors and across-the-line type starters, it serves no useful purpose at all, except possibly to indicate that under certain conditions the motor is apt to start without warning. When used with larger squirrel-cage motors and automatic compensators it prevents full line voltage being applied to the motor at standstill. The protection to slip-ring and direct-current motors is the same.

Diagrams A, B, C, D, E and F show typical examples of low-voltage release and protection.



It is quite apparent, therefore, that low-voltage release should be used only with motors provided with mechanically responsive control, such as float switches or pressure regulators, which are normally expected to start and stop without warning. Using it with motors normally under the control of a workman or attendant introduces a positive source of danger.

Full-magnetic starters provide low-voltage release when they are used with two-wire control. The drawing at *A* shows the wiring diagram of a typical full-magnetic, time-limit-type starter. The master switch may be a float-operated device, a pressure regulator, or simply an ordinary single-pole, snap switch. An examination of the diagram will show that the solenoid is connected to the line so long as the master switch contacts are closed, but the motor is connected only so long as the voltage is sufficiently high to raise the contact arm and short-circuit the starting resistor. Should the voltage fail while the motor is running, the contact arm will fall and cut the starting resistor into circuit, but immediately upon the return of voltage it will gradually rise and accelerate the motor again.

Semi-magnetic starters provide low-voltage release when the motor is accelerated automatically but started and stopped by hand or by mechanical means. At *B* is shown the wiring diagram of a typical starter of this type. The main switch illustrated is simply a double-pole, knife switch but a float or pressure-operated switch of sufficient capacity to handle the current of a small motor directly is often used. The starter illustrated is of the counter emf. type which is often used in this manner with small direct-current motors. The closing coil of the contactor is connected directly across the armature terminals. Should the power fail, the motor will stop, the counter-emf. will fall to zero and the contactor will open, inserting the starting resistor into the armature circuit. When the power returns, the motor will be automatically accelerated as before.

Manually operated starters and speed regulators do not provide low-voltage release.

Table Showing When Low-Voltage Release or Low-Voltage Protection Is Obtained with Different Kinds of Control

Kind of Control		Low-Voltage Release or Protection
Full-magnetic	Two-wire control	Release
	Three-wire control	Protection
Semi-magnetic	Manual start and stop and automatic acceleration	Release
	Magnetic main switch and manual acceleration	Protection
Manual, with low-voltage coil		Protection

How Low-Voltage Protection Is Obtained

Low-voltage protection (sometimes called *under*-voltage protection) affords adequate protection to the motor, the men working around it, and the machinery driven by it. If the motor stops because of power failure, there is no possible chance of it starting again until someone deliberately starts it, and consequently no danger of anyone being hurt by an unexpected start. Accordingly, low-voltage protection should always be provided in connection with motors which are normally started and stopped by workmen or attendants. This is true for all types of motors, direct-current and alternating-current, squirrel-cage and slip-ring.

Full-magnetic starters provide low-voltage protection when used with three-wire control. The wiring diagram of a full-magnetic, time-limit type starter designed to give low-voltage protection is illustrated in diagram *C*. The master switch is customarily a double-button affair, as shown, the start button having normally open contacts, and the stop button normally closed ones. A momentary pressure on the start button connects the closing coil of the solenoid or contactor to the line and starts the motor. An examination of the diagram will show that the connections are such that releasing the button does not stop the motor. The solenoid or contactor establishes its own maintaining circuit (see contact *M* on the diagram) when it closes, and that circuit can only be opened by pressing the *stop* button.

When the power fails, however, the contact arm falls, or the contactor opens, opening both the power circuit and the control circuit. Since there is only one possible way for the operating coil to become energized again, the motor remains at stand-still until someone deliberately presses the start button. At *D* is the wiring diagram of an alternating-current starter of the across-the-line type arranged to give low-voltage protection.

Semi-magnetic starters and speed regulators can be arranged to provide low-voltage protection when the main switch is a magnetic contactor and the accelerating or speed-regulating device is manually operated. The wiring diagram of such a combination as used with an alternating-current slip-ring motor is given at *E*. An examination of the diagram will show that it is impossible to close the main line contactor until all of the starting or speed-regulating resistor is in circuit, since moving the contact arm away from the first point automatically opens the circuit with the start button.

Manually operated starters and speed regulators, when provided with a low-voltage coil, always afford low-voltage protection. The wiring diagram at *F* is that of a typical direct-current starter. A device of this type *cannot* give low-voltage release, because any interruption of the main circuit caused by the functioning of the low-voltage device is necessarily maintained until the circuit is manually re-established.

Low-voltage coils are practically always provided on direct-current, manual starters and speed regulators. Resistance-type starters for alternating-current squirrel-cage motors should be provided with low-voltage coils. Compensators always give low-voltage protection. Manually operated starters and speed regulators for slip-ring motors designed to handle the secondary current only should be interlocked with the main line primary contactor to give low-voltage protection.

Some Ways to Locate and Remove

Troubles in D. C. Armatures

That Sometimes Develop When an Armature Is Being Wound

MUCH LABOR may be saved when winding armatures if coils are tested as they are placed in the slots. Practically every man responsible for maintenance can vouch for this from experience. If trouble is found it will be much easier to make repairs at this time than to make them after the job has been finished. Failure to "be sure before going ahead" is often due to a lack of appreciation of the importance of testing or to a limited knowledge or a misunderstanding of the best methods of testing the windings as they are made.

In this article Marin Phillips tells what tests to make and gives some very practical hints on correct methods of winding and connecting the coils so as to prevent trouble in the first place, with details of how to remedy defects which may develop.

By MARIN PHILLIPS

Electrical Foreman, Thilmany Pulp and Paper Co., Kaukauna, Wis.

WHEN WINDING an armature the coils should be tested as they are put in place. After each coil is put in, it should be tested for grounds and for short-circuit with other coils. Often a great deal of labor is saved by testing at this time instead of waiting until all the coils are in place. If a defective coil is found after all the coils are in place, the top sides of several coils must be removed before the defective coil can be taken out. For making such tests the test-lamp method is simple, reliable and easily handled.

Of course it is better to prevent troubles than to find them and remove them. A little care in winding will usually result in a faultless job. In placing the coils in the slots it is very important to keep the coil ends in a line parallel to the ends of the core as shown in *B* of Fig. 1. If they are not kept in a straight line, the bends will work closer to the end of the slot and the end of the coils will be crowded to one side. By the time the coils are half in it will be very difficult to put in another coil. The straight side of the coil must extend at least ½ in. out of each end of the slot before turning. The first few coils that are placed in the slot will have only one side put in at first, leaving the other side to rest on top of the slots, protected by a sheet of insulating material. For instance, if the coil pitch is 1 and 6 the first five coils would be slipped into the slot without paying much attention to how straight they are, for they will be loose in the slot and can be straightened later.

However, when the sixth coil is placed in the slot they must all be very carefully centered on the core, having the straight sides extending the same distance out of each end of the slots. Then the top side of the sixth coil will be placed in the slot on top of the bottom side of the first coil. After this the coil must be squared crossways with the armature, so that a line drawn through the center of the coil will be parallel with the slots as illustrated in *B* of Fig. 1. In *C* of Fig. 1 is shown how the coil is apt to look if it is simply placed in the slot without paying any attention as to whether it is square.

This point may seem of very little importance, but the time lost in getting the coils shaped properly is more than regained before the winding is completed. By keeping the winding straight it will not only look well but will insure first-class workmanship by not having to hammer and force the coils in place along towards the last. Drifts for keeping the coils straight and raising them will be described in a later article. Sometimes the first four or five coils that have both sides placed in the slots will not have sufficient room at each end to drive in the slot wedges, because the coils that have only one side placed in the slots may project above the surface of the armature. If so, the first few wedges may be left out until the coils are all in place.

Testing for Grounds

Drawing *A* of Fig. 3 shows a way of testing each coil as the winding progresses without taking up very much time. Two wires are run from the electric light circuit with a 110-volt lamp in series with one of them. One wire is connected to the iron of the armature by letting the shaft rest on it. The other wire is free, and as each coil is placed in the slot the loose wire is touched to either the coil leads *a* or *b*. After touching the coil lead then touch the wire to the iron and note if the lamp lights to serve as a check on the connection of the other wire to the iron core.

In testing the armature it is very important to have it on an insulated support. When the testing is being done with wires from a lighting system, there may be a ground on the circuit at some place in the building. Take, for an illustration, the armature and the connection shown for testing it in *B* of Fig. 3. The armature is resting on a pipe stand which may be in contact with a steel floor or against the heating system, or there may be some workman shooting trouble on a motor touching a machine that is in contact with the steel work of the building. Suppose the lighting system is a two-wire arrangement and that there is an accidental ground or a permanent one on the wire *A*. Suppose that the test lead which is on the grounded wire is then touched to the coil lead first and the other test lead with the lamp connected to it is touched to the shaft. As soon as the shaft is touched the lamp would burn bright, indicating a full ground, which might not be the case. The coil might be free

from a ground and yet current would flow through the shaft and iron core to the frame and through the piping or steel work back to the ground *A*. The armature might be needed immediately, in which case the workman would not have much time to think and this test might cause him a lot of trouble if he failed to discover the mistake.

Now suppose that the test lamp happened to be connected in series with the lead that was grounded as shown by the dotted lamp connection and that this lead was first touched to the coil. Nothing would have shown up until the other lead was touched to the shaft. Then a short-circuit would be the result. The current would flow through the shaft back to the ground and blow the fuse at *B*. If the fuse were very large the short-circuit might produce a flash that would be injurious to the tester. It is for just such reasons as this that great care should be exercised in fusing lighting circuits. A 10-amp. fuse should be the largest unless a small motor is running off the circuit and requires more than 10 amp. for starting.

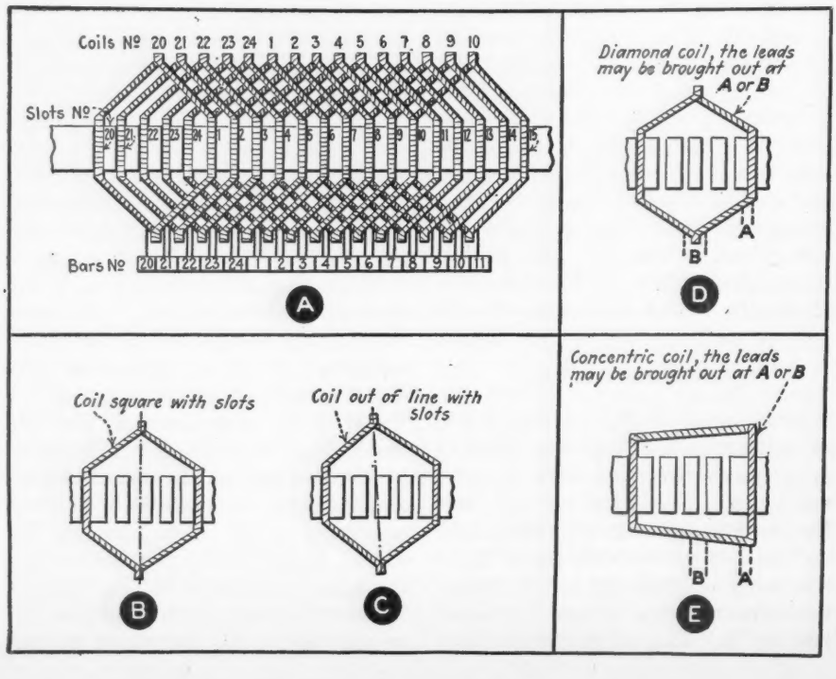
When alternating current is used for lighting, the three-wire system is generally employed. Energy is supplied from transformers that give 220 volts between the outside wires and 110 volts from each outside wire to the middle. For safety reasons, this middle wire is permanently grounded at the transformers. This would give the same misleading results in testing the armature as the method shown in *B*, Fig. 3.

The small transformer shown in *C* of Fig. 3 is very handy and convenient for testing on grounded circuits, as a ground on the primary side as at *A* will not affect the test leads on the secondary side. Such a transformer can be rigged up with a set of small fuses and the lamp inside of a small box with a handle on it, making a neat outfit. The core for the transformer is made of old transformer-core iron of the dimensions given in the drawing. The primary and secondary coils are wound with 600 turns of No. 22 single-cotton-covered enameled magnet wire, well insulated from the iron.

When a grounded coil is located and it is not known where the ground is, the way to find it is to raise the side of the coil that is in the top of the slot. The chances are that the ground will be in the top of the slot, rather than in the bottom. The bottom half of the coil is not so apt to be damaged while being placed in the slot, as there is not another coil side in the slot and there will be plenty of room to put the wires in without having to force or hammer them. Of course if the bottom of the slot was not filed smooth of all projecting laminations or burrs caused from burnt-out coils, then when the top side of the coil is put in place and perhaps hammered down with a fiber tool, it is likely to cut the slot insulating cells and ground the side of the coil that is in the bottom of the slot. On an old armature a ground will be present in the bottom as often as in the top of the slot, due to oil or water getting down

Fig. 1—The diagrams show different types of coils and how they lie in the slots.

Diagram *A* shows the appearance of diamond coils in place and connected to the commutator bars. Bith coils and commutator are draw as if rolled out flat, to make their shape and position more easily understood. In *B* a coil is shown lined up correctly with the slots, while the coil in *C* has its diamond points out of line with the slots, which will result in a poor winding. *D* and *E* show, respectively, a diamond coil and a concentric coil with two ways of bringing out the leads.


Coils Nº 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10
Slots Nº
Bars Nº 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11
A
Diamond coil, the leads may be brought out at A or B
A or B
B
A
D
Coil square with slots
Coil out of line with slots
B
C
Concentric coil, the leads may be brought out at A or B
B
A
E

I Don't Know What You Think—

But when I read this article by Mr. Phillips I found that he was discussing what I might call one of my pet hobbies—thorough testing of the work while it is in progress. How many times have you seen a man finish winding and connecting up an armature, or doing some other job, and then find that through carelessness or a slip of some sort there were defects present which took nearly as much time to find and repair as was required to do the job in the first place. Maybe this has happened to you personally. I know it used to happen to me, until I found out how to avoid it by checking up my work at frequent intervals.

And perhaps you have noticed, as I have, that these mishaps usually occur on the jobs that come in with a big red ticket marked RUSH attached to them. I have often heard these occurrences referred to as the doings of Old Man Hard Luck, but I think it would usually be better to blame them on his brothers, Old Man Carelessness and Old Man Hurry.

The idea back of this constant checking and testing, in which I believe so firmly, is that it always pays to take time enough to do a good job, keeping in mind what the requirements of that job are. Cutting corners and skimping may save a few hours' time, but you run a big chance of losing these hours and perhaps many others by having to patch or do the job all over again.

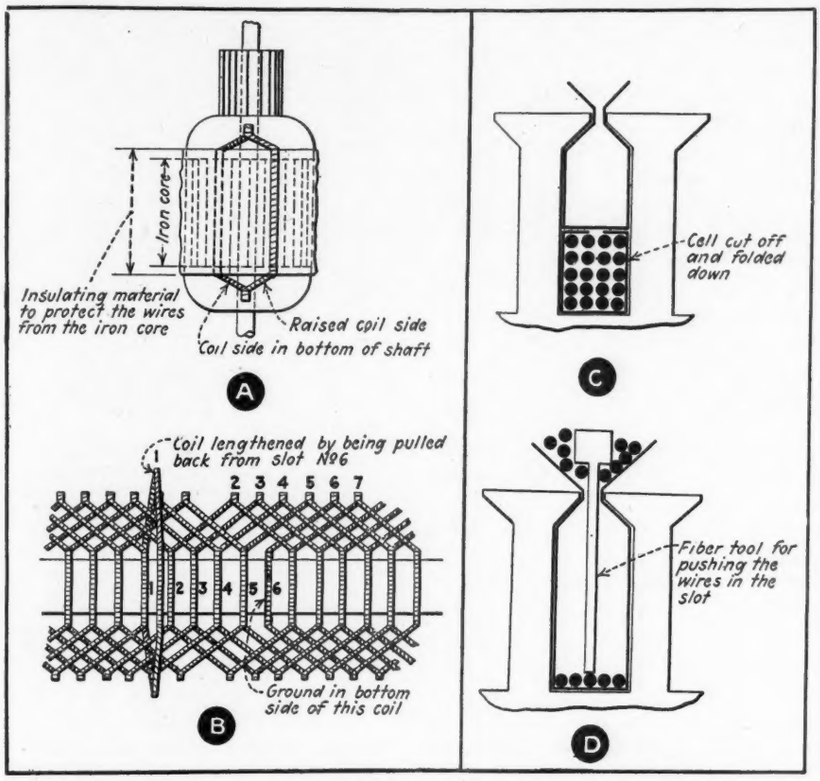

Iron core
Insulating material to protect the wires from the iron core
Raised coil side
Coil side in bottom of shaft
A
Coil lengthened by being pulled back from slot No6
1 2 3 4 5 6 7
1 2 3 4 5 6 7
Ground in bottom side of this coil
B
Cell cut off and folded down
C
Fiber tool for pushing the wires in the slot
D

Fig. 2—Methods for lifting out coils and placing turns in the slots.

Before lifting out the sides of a coil, a piece of insulating material such as fiber should be placed over the core as shown at *A* to prevent the coil being skinned by the iron. When the bottom side of a coil is to be lifted out of the slot, all coils that overlap this coil must be bent back out of the way as shown at *B*, where coil No. 1 has been bent back. Coils 1, 2, 3, 4 and 5 must be bent back before the bottom side of coil 6 can be removed. *C* shows how a damaged cell insulator may be cut off and folded down over the bottom coil. Another cell insulator is then placed over this to receive the top coil. *D* shows how a fiber tool is employed to feed the turns into a slot one layer at a time.

into the slot. In either case when starting to remove the ground, the top side of the coil that is grounded should be raised first. Very often the ground will be found in the top of the slot in the last turn or two, and can be removed without disturbing any of the other coils.

Raise One Coil at a Time

If the turns of a coil are taped together, the entire side must, of course, be raised. If, however, the turns are free from each other they should be raised one at a time. When starting to raise the turns of wire out of the slot it is very important to see if the coil turns too short at the end of the slot, producing a tension on the turns of wire around the corner of the slot. This is a condition under which it is almost an impossibility to raise the wires out of the slot without skinning the insulation and damaging the slot-insulating cells, which will greatly increase the amount of work required to repair the armature. When such a condition is encountered the coil, if possible, should be pried back a little so as to have the turns of wire come out of the slot straight before turning, which will relieve them of the tension around the corner of the slot, and will make the job of getting out the turns much easier, therefore speeding up considerably the repair of the armature.

Every time a turn is taken out, the coil should be tested to see if the ground is still in the coil. In this way, no more turns will be taken out than are absolutely necessary. To do this, use a 110-volt lamp as shown in *A* of Fig. 3. Clamp one of the test leads onto the shaft and the other to a lead of the coil. The lamp will burn steadily until the wire that is in contact with the iron is moved, at which time the light will go out, indicating that the ground is in the turn last removed. If all the turns are taken out before again testing the coil, it might be that the first one or two turns taken out contains the ground, and the work of taking out the other turns and putting them back in will be all for nothing; besides there is also the chance of skinning the insulation off of a few more turns. But suppose that all the turns are taken out of the slot and the ground still remains in the coil. Then it is evident that it is in the other side of the coil, which is in the bottom half of a slot. The turns of this side are then removed singly until the grounded turn is located.

How to Repair Grounded Coil

When the grounded turn is found, the coil may be repaired or replaced by a new coil. To repair grounded turns they should be very carefully taped with silk tape, winding it on quite tightly so as to take up as little room as possible and to insure its not slipping off of the bare spot. Silk tape only should be used, as there is usually little room in the slot to spare. By using any other kind of tape there would not be room in the slot to get all the turns in. Before attempting to put any of the turns in the slot, the coil must be pulled back a little beyond the slot in which it will lie, so that when the pressure on it is relieved it will spring back and rest on the top of the slot. To pull the coil over, it is grasped at each end of the slot and pulled with equal force at each end of the coil, at the same time straightening it so that it will go in the slot without being bent around the corners. If the turns have to be pulled over the corners of the slot while being fed in, there will be a tension on them and they will crowd to one side of the slot instead of lying side by side in the bottom. It will then be much harder to put in the last turns. The wires must lie straight in the slot without crossing, as every crossing takes up the space that should be occupied by the next layer.

In case any of the slot-insulating cells are damaged while lifting the coils, they may be renewed if they are not damaged below the top of the bottom coil. They are repaired by cutting the cell off a little above the top of the coil and folding it over as illustrated in Fig. 2 at *C* and placing a new cell on top of it. After the coil is straightened out well so as to lie in a straight line above the slot, the turns can be pushed down in the slot with a piece of fiber shaped as shown in Fig. 2 at *D*. This drawing also shows the method of feeding the turns into the slot. The fiber tool is worked down between the top layers, care being taken not to push any turns down except those in the bottom layer. When the layers are placed in the slot one on top of the other in the right position,

the coil will lie straight and not take up much room, but if some of the top or middle turns are pushed in the slot before the lower turns, the coil will be bowed up at each end and will have to be hammered down into place.

Test for Ground After All Coils Are in Place

When the last coil has been placed in the slots the coil ends may all be joined together by means of small bare wire. Then a high voltage is applied to the winding and the shaft or armature core as shown in Fig. 4. About 600 volts is sufficient to test armatures for 110 volts and 1,000 volts for 220 volts, while for 440 and 550 or 600 volts the test should be made at 1,500 volts. Such an insulation test as this should be made on all newly wound armatures for about a minute, as it will insure sending the armature out on the job well insulated and not apt to break down and ground at points which are weak, but might not be detected by a 110-volt test.

In testing with high voltage a resistance to limit the current should be placed in series with the primary side as shown. A lamp (or two or three lamps in parallel) will serve well for this purpose.

It must be remembered that 1,000 volts are dangerous to life. A good contact with the line is almost sure to prove fatal. Fig. 4 shows the ideal arrangement for the high-voltage test leads. With this method of supporting the test wires they will be up out of reach instead of lying around where they may be accidentally touched and cause a serious accident. It is a good policy to have the ends of the test leads made with a kind of hook on them so that when the testing is completed they may be hooked together and let up out of reach. Then the lamp will be burning which will prevent the tester from forgetting to turn off the high voltage.

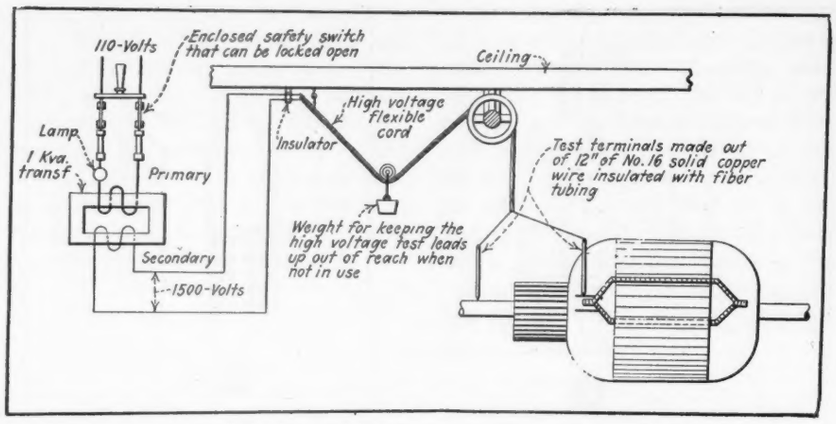
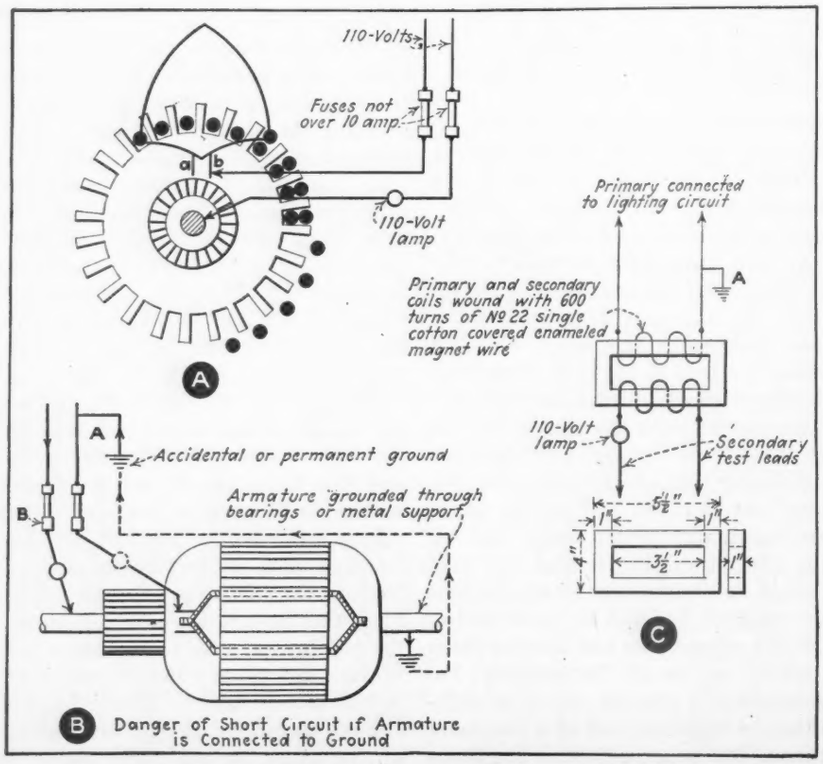

110-Volts
Enclosed safety switch that can be locked open
Ceiling
High voltage flexible cord
Lamp
1 Kva. transf
Primary
Insulator
Test terminals made out of 12" of No. 16 solid copper wire insulated with fiber tubing
Weight for keeping the high voltage test leads up out of reach when not in use
Secondary
1500-Volts

Fig. 4—High-voltage test for grounds after all coils are in place. This shows a scheme for keeping the high-voltage test leads out of the way when they are not in use. About 600 volts is used for 110-volt machines, 1,000 volts for 220-volt machines, and 1,500 volts for 440-volt to 600-volt machines.

Fig. 3—Testing a coil for grounds after placing it in the slot. A 110-volt circuit with a lamp in series is employed as shown at *A*. The armature must be on a support which insulates it from the ground. If not ,a short-circuit may result as illustrated by the dotted line in *B*. To avoid this danger, a one-to-one transformer may be used as shown at *C*.



The ground can usually be located by a small spark or buzzing sound. Very often the cause of a ground is that the coil side is not brought out straight from the slot but is run out at an angle. Instead of the coil making the bend free of the end of slot, it is bent around the corner of the slot, which may crack or cut the slot insulation. If the coil is being crowded by the other coils enough pressure will be exerted on the corner of the iron laminations to cut the insulation on the wire and ground it. Such grounds can very often be removed by hammering the corner of the coil back with a fiber drift, driving the slot wedge back and forcing a piece of mica or fish paper between the coil and iron at the point where it was grounded. Then drive the wedge back over it to prevent it from working out.

If the ground is in the cell sections of a coil, raise the top section one turn at a time. Care must be taken not to damage the insulation, fish paper or empire-cloth slot-insulating cells, for in order to renew them, still more coils would have to be disturbed, and while doing so more might be damaged. Test the coil after each turn is raised. Test with 110 volts to see if the ground shows at this voltage. If it does not, use the higher voltage, 1,000 or 1,500 volts. Sometimes the coils will be so close together that the top side of the grounded coil cannot be raised without lifting a few turns out of the coil in the slot next to it, that

is, the coil adjacent that overlaps the grounded coil.

If the ground is not found in the top side of the coil, it is in the bottom side. To remove this side of the coil the top sides of the coils that cross it must be raised. To raise them first cut a strip of some kind of insulating material or pasteboard a little wider than the slots are long, and place it over the iron core, as shown in *A* of Fig. 2. This will protect the insulation on the wire from being skinned when the coil sides are raised and pulled back over the core. It is very important not to neglect this for if this precaution is not taken, more coils are almost sure to be damaged by coming in contact with the iron. The first coil side to be raised is the one on top of the one that is to be taken out. When pulling the coil back it is necessary to push down on it at the same time, forcing the sides closer together and making the coil narrow. This will bring the top side almost down on the iron, and that is why the strip of insulating material must be placed on the core to prevent the coil from coming in contact with it. It is necessary to push the coil sides close together in order to make the coil long enough to slide back over the ends of the other coils as shown in Fig. 2 at *B* where the ground is in the bottom of coil 6. The right-hand side of the long coil (coil 1) has been taken out of slot No. 6 and pulled back over the ends of the other coils until it is over No. 1 slot. Before the bottom side of coil 6 can be raised it will be necessary to take out the top sides of coils 1, 2, 3, 4 and 5. These coils must be bent back out of the way in the same manner as coil 1 is shown bent back. After the defective turns are found they are insulated with silk tape as already prescribed. If necessary a new coil is substituted.

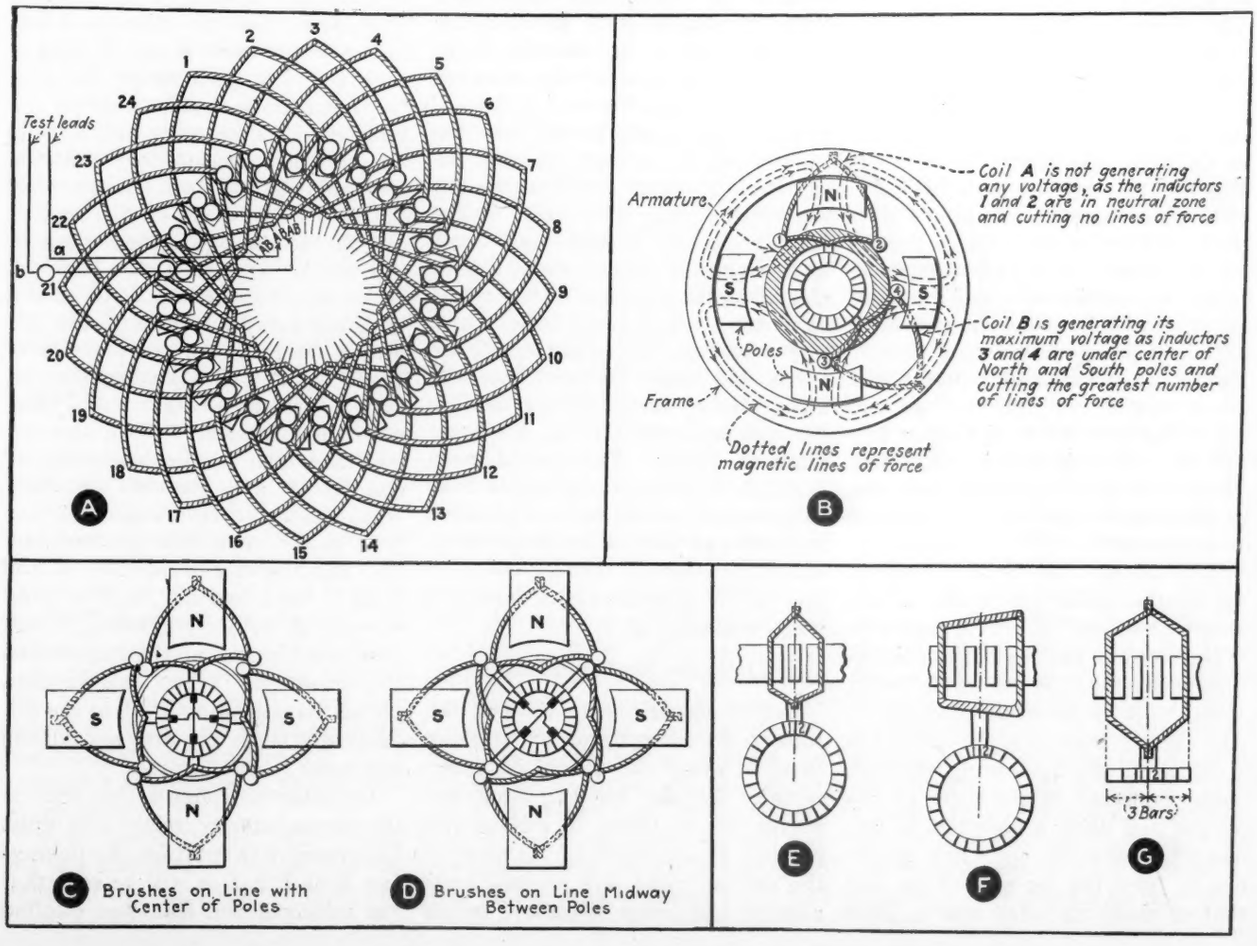
Fig. 5—Connecting coil leads to the correct commutator bar.

Diagram *A* shows how test leads are used to find the starting and finishing leads of a coil. *B* explains where a coil should be while its commutator bars are under the brush. Coil *A* in drawing *B* is in the correct position, while coil *B* is in the worst possible position. *C* shows how to connect a coil whose leads come from its center. *D* shows how to connect a coil whose leads come out at one of the cell sections. *F*, *E* and *G* illustrate how to connect the first coil to the right bars. After this is done the other coils are connected in rotation.

In replacing the coils the reverse order is followed. First, the bottom side of coil 6 is put in place. Then the top sides of coils 5, 4, 3, 2 and 1 are replaced in the order named. This should be done with great care so as not to damage the insulation. Each turn should be carefully looked over as it is being put in the slot for places that were skinned when raising the coils.

Short Circuit May Develop Between Coils

Before proceeding with any of the connections, the winding should be tested for short circuits between coils. This can be done very easily by using 110 volts and the test lamp. Start out on any coil, say, for an example, coil No. 1 in *A* of Fig. 1. Touch one test lead to either lead of coil No. 1 and touch the other test lead to a lead of coil No. 2. If a short circuit exists between these coils at any point where they cross, the test lamp will light. But by inspecting the winding it will be seen that the right-hand side of coil No. 1 crosses the left-hand side of coils 2, 3, 4 and 5 and lies in the slot on top of coil No. 6. So it can


Test leads
Armature
Coil A is not generating any voltage, as the inductors 1 and 2 are in neutral zone and cutting no lines of force
Coil B is generating its maximum voltage as inductors 3 and 4 are under center of North and South poles and cutting the greatest number of lines of force
Poles
Frame
Dotted lines represent magnetic lines of force
3 Bars
A
B
C Brushes on Line with Center of Poles
D Brushes on Line Midway Between Poles
E
F
G

be readily seen that in order to test the winding thoroughly for short circuits it will be necessary to have one test lead on the lead of coil No. 1 while moving the other lead around until it has touched one of the leads of all the coils which coil No. 1 crosses. Then change the first test lead from coil No. 1 to coil No. 2 and touch the other test lead to the leads of coils 3, 4, 5, 6 and 7. Continue in this manner all the way around the armature.

If this procedure is followed very carefully while testing the winding it will show if any short circuits between coils were accidentally created. The main thing to watch in order to make the test accurate and reliable, is to be careful not to miss any coil leads while changing the test lamp leads. In making such a test an ordinary test clip for use on the first test lead will be found very useful, as it can be snapped on the coil lead. Then both hands will be free to select the coil leads over to No. 6 as the other test lead is moved from one lead to the next. If this testing is carefully done so as not to miss any of the coils that cross one another, and no light is obtained, the coils are free from short circuits between one another.

Should the test lamp light at some point in the winding it will indicate a short circuit between two coils. The first thing to do when proceeding to locate the short circuit is to separate the coil leads a little by pulling them apart or running a thin piece of fiber in between them. In the meantime have the test lamp connected on to the coil leads temporarily so as to have the lamp burning while exploring for the short circuit. Then when the short-circuited wires are separated the light will go out indicating just where the short circuit is. The damaged insulation, which may only be a small spot, can be repaired by reinsulating with silk or cotton tape.

But suppose the short circuit is not in the leads but exists in the coils themselves. It will probably be at the front or back end of the armature where the coils cross. It can in some cases be ascertained at which end of the armature the coils are short circuited, by leaving the test lamp connected to the coils as explained and using a fiber tool to run down between the coils and gently pry or force the top side of the coil that is short circuited over a little from the coil under it. If the wires are moved or separated at the point where they are bare, the test lamp will flicker or go out entirely, indicating that the short circuit between the two coils has been opened. If the coils should be left thus bent apart it would in most cases be inviting trouble later on of a serious nature, as they would gradually work back to their old position by the action of centrifugal force and vibration. This would cause the short circuit to reappear and probably burn out one or more coils.

If prying the top coil over a little at the front and back of the armature does not reveal the location of the short circuit, it will then be necessary to leave the test lamp connected to the coils that are short circuited and gently raise the turns of wire until the test lamp goes out. Then the wires that have their insulation damaged must be repaired by taping with a good thin tape. In this case silk tape is the ideal tape to use. Several layers can be wound on without taking up very much room. If only one or two turns have the insulation damaged on them for a very short distance, they may be repaired by taping and inserting a strip of empire cloth between the damaged points, interlacing it so that it will be between the damaged turns and the good ones. A strip of empire cloth should be laid over the bottom coil to separate it from the top one. The test lamp may be left connected to the coils while replacing the top one, to serve as a check by lighting up if the short circuit should again develop. This would save the trouble and time which might be required to put in all the turns and then discover that the short circuit was again present in the coil and probably at the same place as before. This would mean that all the turns would again have to be raised. When the coil has been replaced and there is no short circuit existing, it should then be tested to find out if a ground has developed while replacing it.

Locating Starting Leads

Before beginning to connect the coils to the commutator the starting leads of every coil should be determined. In case the coil leads are partly out of sight, it will be impossible to see which is the start of the coil as there will be two leads coming out close together, which will be the beginning of one coil and the end of another, or the ends of two different coils. Such conditions are not very often met with except on small armatures wound with concentric coils, having the straight side of the coil from which the leads are brought out as at *A* in drawings *D* and *E*, Fig. 1, lying in the bottom of the slots. Under these conditions the leads will have to be tested out to know which is the beginning of each coil. Take for example the drawing in *A* of Fig. 5 and say that we started to connect lead *A* of coil No. 1 to the commutator. It will be seen that there are two leads, *A* and *B*, coming out between coil No. 1 and No. 24. We want to know which one is lead *A* of coil No. 1. This can be located by placing one lead of the test lamp, say lead *"a,"* on one of the coil leads between coils 1 and 24. Then with the other lead *"b"* from the test lamp, touch coil leads *A* and *B* between coils No. 1 and 2, then if the lamp lights on one of them it will indicate that the other coil lead that the test lead *"a"* was touched to, is the start of coil No. 1 and the coil lead *B* to which the *"b"* lead of the test lamp was touched is the end of coil No. 1.

Suppose that no light was obtained on coil leads *A* and *B* between coils 1 and 2, then swing the lead *"b"* from the test lamp over to coil leads *A* and *B* between coils 23 and 24 and touch each of them. If the test lamp lights it will indicate that the test lead *"a"* is on the end of coil 24 instead of the beginning of coil No. 1. Then shift the test lead *"a"* from the coil lead *B* to *A* and with the test lead *"b"* find the coil lead *B* which is the end of coil No. 1 and bend it back leaving the coil lead *A* project straight out. Then move the test lead *"a"* to the coil lead *A* which is the beginning of coil No. 2, and was left by itself when the lead *B* from coil No. 1 was bent back. Then with the test lead *"b"* find the end of coil No. 2 and bend it back leaving the beginning of lead *A* projecting straight out. Continue like this all the way around the armature. When this is completed the beginning of all of the coil leads will be in one row, and all the end leads in another row.

In order to connect the coils to the commutator correctly they must be connected in rotation. By inspecting *A* of Fig. 5 it will be seen that the left-hand coil lead was selected

for the beginning of all the coils. The first connection to the commutator can be located by inspecting the position of the brushes on the commutator. This is very important and failure to do so may result in having to rewind the armature if the brushes can not be shifted far enough to locate them in their correct relation to the coil connections. Even if the brushes can be shifted quite a way it is a safe plan to try and keep them in their old position. The brushes must be so located that they will short circuit the coils whose sides are in the neutral zone, which is the space midway between the pole tips. In this position the coil will not be cutting the flux or lines of force flowing from the field poles to the armature core. Drawing *B* of Fig. 5 shows the path of the magnetic lines of force for a four-pole armature. The lines of force given off from the north poles flow down into the iron core of the armature and divide. Part will flow each way and through the armature, the south poles, and the iron frame back to the north poles as arrows show.

In *B*, of Fig. 5, there are only two coils shown in position on the armature for the sake of illustrating the instants when the coils will have the maximum and minimum voltage induced in them. Take the coil "*A*" in the position shown, the sides are lying midway between pole tips and are not rotating through the path of the flux, and therefore no voltage can be generated by the turns of wire in the coil except a slight voltage due to the counter emf. of self induction in the coil. This is the correct time for the brush to short circuit the commutator bars connected to this coil. At this time very little current flows between the bars through the brush. Now by inspecting coil "*B*" its sides will be found lying directly under the centers of the north and south poles, at which time it will have the maximum voltage induced in it by cutting the lines of force at the strongest point. If the brushes should be set so as to short circuit the coil when it is in this position, a heavy current would flow between the bars which have the coil connected to them, and would cause excessive sparking and burning of the commutator bars making the machine inoperative.

Before going further into connecting the commutator, let us stop and consider the two types of coils that are most widely used on small armatures. Drawings *D* and *E*, Fig. 1, show the well-known diamond and concentric coils which have many good advantages. First, for open slots they can be well insulated before being wound in the slots. Second, they are all the same size on a given armature and can all be wound on the same form. Third, the number of coils to be kept on hand for repairs is reduced to a minimum. But the concentric coil, *E* in Fig. 1, has an advantage over the diamond coil for small armatures and is used most as it occupies less end space.

Other Commutator Connections

Going back to the position of the brushes on the commutator, *C*, Fig. 5. shows the proper setting of the brushes in connecting the coils to the commutator if the coil leads are brought out in the center of the coil. In order to short circuit the coils at the proper time the brushes will be set on a line with the center of the field poles. In *D* of Fig. 5 is shown the armature wound with coils that have the leads brought straight out from one side of the coil. In order for the brushes to short circuit the coils at the proper time they (the brushes) will have to be set on a line midway between the pole tips. When starting out to make the coils for the armature, after the size of the wire and the number of turns are determined, then the position of the brushes on the commutator must be observed in order to know at which point on the coil to bring out the leads. Suppose the brushes were examined and found to be resting on the commutator on a line with the center of the field poles as shown in *C*, Fig. 5. Then it is evident that in order for the brush to short circuit the coil at the proper time, the coil leads will have to be brought out at the center of the coil, as at *B* in drawings *D* and *E* of Fig. 1.

To locate the first coil connection to the commutator for a lap-wound armature, the armature winder would proceed as follows: We will assume that the coils are all in the slots and that they are of the diamond type and test free from grounds. Then an imaginary center line would be drawn through the center of the coil to a mica insulating segment between two commutator bars as shown in *E* of Fig. 5. With the winder facing the commutator he will call the commutator bar on the left-hand side of the mica segment No. 1 and the commutator bar on the right-hand side No. 2. The winder would know beforehand which type of connection was desired. We will assume that it is a simplex progressive lap winding, which is one single winding on the armature advancing around in a clockwise direction. Then the left-hand coil lead would connect to commutator bar No. 1 and the right-hand lead to commutator bar No. 2. After this the center of the coils may be forgotten as the first coil connection to the commutator is the one to figure out, and all the other coils are connected in rotation.

Drawing *F*, Fig. 5, shows the same procedure followed in locating the first coil connection to the commutator on an armature wound with concentric coils. As in the case of the diamond coil, a line is drawn through the center of the coil to a mica segment between two commutator bars and the bar on the left is No. 1 and the bar on the right No. 2.

Another method that may be used in locating the first coil connection to the commutator for an armature with the coils wound full pitch, or to serve as a check on the method just described, is shown in *G*, Fig. 5. Take for the first illustration a four-pole twenty-four slot armature with twenty-four commutator bars. One coil will span one-fourth of the circumference of the armature, and a line drawn straight out from the two slots in which the coil sides lie, will enclose one-fourth of the commutator bars as shown. Then the start of the coil will connect to the third bar to the right of the line drawn straight out from the left-hand side of the coil, and the finish of the coil will connect to the third bar to the left of the line drawn straight out from the right-hand side of the coil. In other words the coil leads are connected to commutator bars on each side of the mica segment that lines up with the center of the coil.

Take for another illustration an armature in which the number of slots divided by the number of poles is not an even number, or for example, a thirty-three-slot armature wound for four poles. Then the number of slots divided by the number of poles would indicate that the coils would lie in slots 1 and 9 spanning eight slots which is only one-fourth of a slot less than full pitch. The fraction of a slot may be forgotten. Then a line drawn straight out from the slots in which the coil sides lie encloses (*Continued on page* 458)

INDUSTRIAL ENGINEER

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Editorial Director

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Chicago, September, 1922

When Employees Are Interested In Safety Work

RECORDS of twelve months' operation of a manufacturing works without a single accident, such as established at the Hawk-Eye Works of the Eastman Kodak Company, shed new light on accident prevention movements. W. G. Woodams, employment manager, in commenting on this safety work, said:

> While our machines are well guarded and as many hazards as possible are eliminated, the secret of what success we have had is but partly to be found in this feature. Many another shop is guarded as well, or even better, but with less favorable results. Therefore, it is in both the use of the guards and the attitude of each individual as he does his work day by day, that the answer is found. For the last five years, while the plant was expanding rapidly and new help was being taken on, we averaged nineteen lost-time accidents annually. During our no-accident year, on the other hand, we employed few inexperienced people and thus avoided one most prolific source of industrial accidents. Skilled operators, careful workmen, long-service employees are not accident makers.

Perfunctory compliance with state factory laws and the posting of scare-head warning signs is far from a correct basis for protecting workers and reducing lost time, excessive repairs, spoiled materials, to say nothing of pain and mutilation through accidents. The plan must be broad enough to engage the personal interest of the heads of maintenance and construction departments and every foreman who supervises men. Mr. Woodams says that when these men naturally and habitually install the guard with the machine and note omissions instantly much detail is avoided and accident prevention then begins with the machine. When a large number of men can feel that they are responsible for new and better ideas in installation and operation of equipment, then safety work is on a truly effective basis. That the maintenance and installation department heads of a large works will function in this way is evidenced by the fact that during the last eighteen months over two hundred safety suggestions have been made by these men in the works of the Eastman Kodak Company on installations that for years had been considered safe and well guarded.

In the works of the National Tube Company at McKeesport, Pa., a handsome bronze trophy bearing the motto "A Careful Man Is the Best Safety Device" is to be awarded to the department showing the best average for accident prevention over a period of two years, and each month during this period it will be awarded to the department having the highest safety record.

The Standard Oil Company of Indiana has established "Safety Courts" in its works organization where careless employees are tried by their fellows, who sit as a jury. When found guilty they are sentenced to two weeks' hard labor such as rolling barrels in a warehouse and the like. This plan has been responsible for a 50 per cent reduction in accidents. These are only indications of ways the initiative and responsibility of the employee can be enlisted in a work vital to himself and important to his company from a production standpoint.

Who Is an Engineer?

JOHN H. DUNLAP, formerly a professor at the University of Iowa, in an address at a recent meeting of the Society for the Promotion of Engineering Education, outlined some of the things that are essential in the mental equipment of a man who bears with merit the title of engineer. This address bristled with common sense. At one point he quoted the late Arthur M. Wellington, who still ranks foremost among combination scholars and engineers who have served as chief editors of the *Engineering News*. Mr. Dunlap gave Mr. Wellington's six acquirements expected of an engineering student upon graduation: 1—A good common school or high school education; 2—Ability to look oneself in the face and not be ashamed; 3—Practical gumption, physical vigor, mental calmness and keenness; 4—Ability to appear at one's best; 5—A book knowledge of engineering; 6—Some practical knowledge of engineering. "Four of these six acquirements apply equally well to anyone, while only the last two apply peculiarly to the engineer," said Mr. Dunlap.

Then he gave the following ten essential acquirements which he believes necessary for the engineer. They are: 1—Every educated man shall know his environment; 2—Every educated man shall know himself; 3—Every educated man shall think well; 4—Every educated man shall write well; 5—Every educated man shall speak well; 6—Every engineer shall know the sources of scientific information; 7—Every engineer shall be skilled in using the method of applied science to solve engineering problems; 8—Every engineer shall be thoroughly trained in costs and values; 9—Every engineer shall prove himself to be an economic asset in his work, and shall understand the commercial and ethical aspects of professional practice; 10—Every engineer shall be taught throughout his course that one of his chief functions is to serve his community.

It is inspiring to note that one well-known educator believes that a man can consider himself educated without speaking seven languages, without demonstrating proficiency in the higher branches of mathematics and without being able to explain the details of the physical and chemical reactions of matter. The first five of Mr. Dunlap's specifications for an educated man apply to anyone. The last five are aimed at technically trained graduates of engineering schools. But of the last five, all but the seventh apply also to the graduate of the

school of experience and observation. As a matter of fact, there are hundreds of men responsible for engineering as related to industrial production carrying various operating titles in the organizations of large industrial works who would be graded high up in all of Mr. Dunlap's specifications for an engineer. And these men add honor and dignity to the title engineer, for they represent a kind of initiative, independence in thinking and ability to carry rsponsibility on which industry, from an operating standpoint, is built.

By all means, a young man should take advantage of a college education if he can, but if he can't, the arena back of the door marked "Engineer," through which the man with a technical school diploma proudly stalks, has devious subway entrances which the man who qualifies with the majority of Mr. Dunlap's specifications will find it possible to use, and in years of maturity be as conspicuous by ability to do things engineering as he who entered in a more pompous way.

Don't Be Afraid to Take Time to Think

IN discussing some of the important viewpoints to be considered in the management of maintenance men, one superintendent of maintenance who has about 150 men under his direction said: "One point I impress upon the foreman is the need of giving men time to think. Many times men are afraid to stop by a machine which may be giving trouble and just watch it for fear that they may be accused of idling. If the man is thinking what he can do and how to do it, he is spending his time very profitably."

Maintenance is as much brain work as hand work and many times if a few minutes more were given to studying what might be wrong and to the best way to correct it, the actual time taken in making the repairs may be cut in half or more. Much of this thinking may be done days in advance of a breakdown. For example, records which show the motors that are available as substitutes for others, analyses of stock in order to keep a sufficient supply of essential repair parts always on hand and easily located, and other similar methods are some of the means for putting necessary thinking on paper so that it is available at any time and cannot be forgotten in the demand for speed in repair work due to an accident.

The Neck of the Bottle in Production

IN every industrial and manufacturing works there is a man who is responsible for the execution of orders that are secured. This man may be a business executive and he may be a combination business executive and engineer, but in any case he is watching orders coming in, the production schedule and the shipment of products produced in order to make money for the company he represents. Under this individual is a group of men who are responsible for the production processes, the continuity of power and material handling service in the plant, and the maintenance of the systems involved.

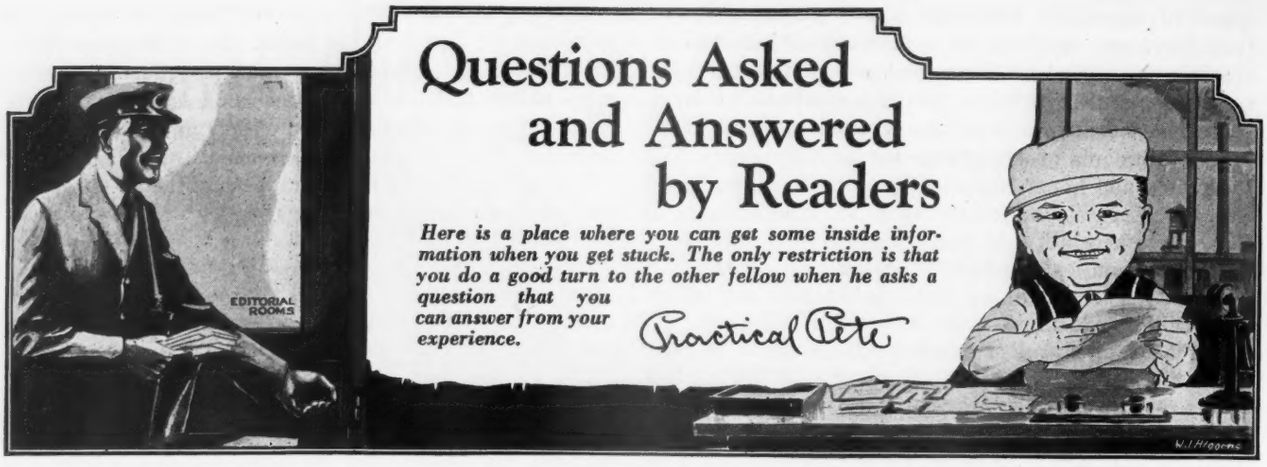
When an order is placed in production, its arrival on the shipping platform completed is predicated on good luck at many points in the long and circuitous path that the raw material takes. An unforeseen hitch through the breakdown of a machine causing one or more delays and the original schedule must be revised if the shipping date is figured closely and orders follow with the familiar rush tag attached.

The neck of the bottle in production, then, is probable and unavoidable losses of time due to unforeseen troubles—troubles that the maintenance man knows all too well on Saturday afternoon and Sunday and sometimes at night following a hard day's work. But with organized inspection programs, systematic overhauling of machines, adequate material handling systems, the curve of the neck of the bottle in production can be decidedly straightened out. When this is done, the foresight of some maintenance man can usually be discovered who appreciated the viewpoint of his boss who watches the production schedule. This is the man who can come closer to estimating the effects of natural wear and tear than anyone else in the works, for, like the family doctor, he knows the ailments of his regular patients and how they respond to treatment. The records of the maintenance man, then, are the best indications of obstructions to smooth production and the extent of insurance that must be taken out from time to time to keep the neck of the bottle straight through improved methods and replacements of old equipment that requires frequent and extensive repairs.

Are You Making Repair Parts At a Profit or a Loss

THE superintendent of the repair shop in almost every industrial works is confronted with the problem of deciding whether certain coils and other repair parts shall be made in the shop or purchased from some manufacturer. This is a question that is not always easy to answer and in any event requires the exercise of good judgment and common sense. There is no economy in making in the shop parts which can be purchased more cheaply on the outside; consequently cost is usually the first consideration in deciding matters of this sort. When the demand for a part is small the cost of making it, considering the investment required for any special equipment that may be needed as well as the labor and material involved, may amount to more than the price asked by the manufacturer. If this were true in the case of only one or two parts which are made in the shop, the loss might not be very serious, but if a number of different parts are being made under these conditions the aggregate loss may be too large to be overlooked.

The fact that the necessary equipment and men are available does not always mean that a given part can be made better or more cheaply than it can be purchased. Before deciding to make any parts which can be bought without difficulty it is advisable, particularly if the demand for them is small, to estimate or determine as closely as possible the cost of making them and then compare this cost with the manufacturer's price. In fact, it is advisable to make a periodic check of the cost of all parts which are made and compare it with the price at which these parts can be bought. Such an investigation will show whether any of the men or machines now employed in making repair parts can be used to better advantage.


EDITORIAL ROOMS
Questions Asked and Answered by Readers
Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.
Practical Pete
W. J. Higgins

Who Can Answer These?

Types of Controllers—What is the difference between a current-limit and a time-limit design of controller? Please explain the advantages in the proper application of both designs when used on direct-current motors.
New York City. M. F.

* * * *

Testing Motor Field Coils—Is it good practice to apply voltage across the shunt fields of a motor for several hours to test for heating? I am having trouble with the blowing of the main fuse on my generator, although the machine is not overloaded. Can you put me next to the cause of this trouble?
New Orleans, La. A. C. H.

* * * *

Methods for Changing Frequency—Please explain how the frequency of a supply circuit from an a. c. generator can be changed to a higher or lower value. Can this be done by stationary apparatus; that is, without moving parts, and if so, please explain the method and equipment used?
Brooklyn, N. Y. A. D.

* * * *

What Is the Average Coil Throw for D. C. Motors of Different Numbers of Poles?—In one motor with 35 slots and 105 commutator bars, a coil throw of 1 to 10 makes the winding come out one slot past the starting point. By using 105 coils, three coils per slot, and connecting the commutator bars 1 and 53 would the winding be correct? In the case of a motor with 40 slots, 79 commutator bars and a four-pole wave winding, would a throw of 1 to 10 and 80 coils with connections to the commutator of 1 to 40 give a correct winding?
Youngstown, O. R. F. D.

* * * *

Grounding Distribution Circuits.—Please publish the following to be answered by some of your readers: In our plant we have a 3-wire system for lights, of which the neutral wire is grounded at the transformer. The National Code reads: "If a system is grounded at the transformer it must also be grounded at each distribution box, or at intervals through the plant." We do not happen to have the grounds at intervals in the plant and that is where part of our trouble lies.

I was called to repair some lights in one of our departments with the complaint that some were very bright and others very dim. Upon arriving there I turned out all lights and took each one separately. Circuit No. 1 did not light; circuit No. 2 was burning about 220 volts, or twice normal; circuit No. 3 burned normal. Upon changing circuit No. 2 to normal, circuit No. 1 also burned normal. Can anyone explain this? What good is the ground at the transformer without other grounds at intervals throughout the plant? What harm could result should the permanent ground be removed?
St. Louis, Mo. E. H.

* * * *

Small Motor Windings—I have a three-phase, 110-volt, 60-cycle Robbins & Myers fan that is self-starting but has no centrifugal switch. I have been told that it receives its necessary starting torque through a small compensator or choke coil. I also have a 110-volt, 60-cycle Westinghouse fan motor with a regular split-phase winding without a centrifugal switch but with a reactance coil. Will someone kindly explain the action of these motor windings, and how the revolving field action in starting is caused, why one is wound three-phase and one split-phase and still both use a compensator?
Brooklyn, N. Y. I. T.

* * * *

Changing Winding of Induction Motor—What changes should be made in rewinding a three-phase, four-pole, 220-volt, 20-hp. induction motor for operation on a two-phase, 440-volt circuit? The original stator has 48 slots with 48 coils of 14 double turns of No. 14 wire connected two-circuit delta with a throw of 1 and 10. What would be the result if only the throw of the coils is changed to 1 and 12?
Fairfield, Me. M. D. B.

* * * *

Device for Testing Windings of Small Motors—Will someone be good enough to describe a small testing transformer or similar device such as described on page 45 of the January issue of Industrial Engineer, that can be used for testing the windings of fractional horsepower motors for short-circuits, grounds, open circuits, and the like?
Nanty-Glo, Pa. S. J. S.

Answers Received To Questions Asked

Heating of Low Voltage Release Coil on Compensator.—We are having trouble with heating of the low-voltage release on a 10-hp. compensator used with a 220-volt a. c. motor. The coil is 3 in. long, 3 in. in diameter with the diameter of core tube 1⅛ in. It has approximately 3,000 turns of No. 27 silk-covered enameled magnet wire.

The core is made from iron laminations taken from an old transformer, the dimensions of which are as follows: Length 4¾ in.; diameter, 15/16 in., approximately.

The inside diameter of core tube is 1 in. The coil used gets hot after about one hour's operation. We would appreciate it if someone will help us by giving a solution of this trouble.

Walsenburg, Colo. E. P. McC.

In the July issue of INDUSTRIAL ENGINEER E. P. McC. mentioned a heating trouble with a low voltage release coil on a compensator. I think if he will notice whether the armature is attracted sharply and quickly or whether it lags slowly he will find that the winding is short-circuited if the armature lags as there is not enough magnetic force; but if the armature comes up quickly he will find he has too much wire and the winding is acting as a heating unit.

In the latter case, cut the wire down one-third. He does not state the make of the machine or compensator or whether it is 1, 2 or 3-phase. If he will state this I will be only too glad to help him in any way I can.

I am glad this department is in your paper as it helps me and everyone else who reads it. I don't want the boys to think that I am a Johnny Wise, but I want to help all I can and would like to see this department increase as it not only helps us all

but it is the means of an unseen friendship.

Holliston Mills, Norwood, Mass. WM. HARPER, Chief Electrician.

* * * *

Connecting A. C. Generator as a Motor.—We have a 30-kva., 240-volt, three-phase, 60-cycle, revolving-field, two-slip-ring, separately-excited generator which we wish to use as a motor. Could we make it self-starting by installing a double-throw, double-pole, switch across the exciter, to short-circuit the rings until up to speed and then throw in the exciter?

Richmond, Va. H. K. B.

Your method of short circuiting the rings would work on a smaller generator but with this size you run a chance of inducing enough voltage in the field winding to break down the insulation because of the high impedance. It would be better to open up the connections between coils but this is impracticable on a rotating field. The best thing to do is to belt to the generator a small 5-hp. motor with pulleys to drive the generator at the proper speed; after the generator is up to correct speed excite the field and synchronize. After this the belt may be thrown off. This is easy if you select the pulleys carefully.

Boston, Mass. EDWARD A. GIBBS.

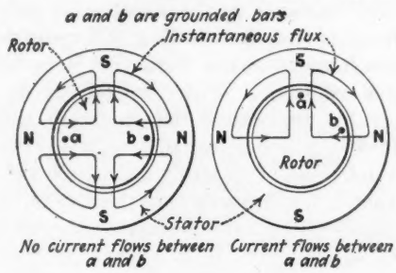
* * * *

Grounding of Squirrel-Cage Rotor Bars.—I would like to have someone answer the following questions: Why will some squirrel-cage rotors run when the bars are grounded solid in the core and others if grounded only slightly, maybe one or two bars, will burn and heat or lose power? I, myself, have hammered the laminations in to ground the bars where they could not be reinsulated. I have also grounded the end rings solid after perfectly reinsulating the bars, yet grounding a couple of those bars would impair the efficiency.

Philadelphia, Pa. G. W. H.

In regard to the question of the "Grounding of Rotor Bars," I know one explanation of the fact that the bars will sometimes heat and at other times will not. For instance, a four-pole, three-phase motor could have two bars grounded on opposite sides of the rotor but as the bars would be in similar magnetic fields, the grounds would cause no disturbance. The opposite sides of the stator of a four-pole machine are of the same polarity and induced emf.'s in rotor bars oppose each other at these points. Consequently no currents will flow in the circuit made by the rotor bars, the end rings and the two grounds as shown in the diagram at the top of the next column.

If the double ground exists in the rotor of a four-pole machine at points other than 180 deg. then the emf.'s will add vectorially and cause circulating currents in the circuit composed of rotor bar *a*, end ring bar *b*, ground through rotor core to *a*. These currents depend



Action of stator flux on rotor bars

on the resistance of the grounds and the heating (I^2R) also depends on the resistance of ground contacts. High resistance will give high heating effect if there is voltage enough to cause heavy current. The worst condition on a four-pole motor is when the bars are 90 deg. apart.

In general, currents and resistances will depend on the points of grounding in respect to the instantaneous field positions, their proximity to end rings (which affects the length of the path), the number of grounds and the ohmic resistance of the grounds.

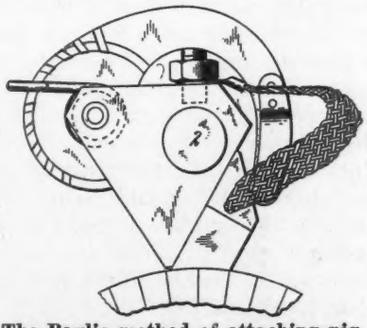
Boston, Mass. EDWARD A. GIBBS.

* * * *

Connections for Motor Brushes.—The writer would like to know what has been found best practice in fastening the flexible wire (pig tail) on carbon brushes for motors. I would like to see a sketch and an explanation of just how the wire is fastened to the brush.

Racine, Wis. T. G. L.

We have noted in your issue of July, under "Questions Asked and Answered by Readers," a question by T. G. L., of Racine, Wis., concerning "Connections for Motor Brushes." It might interest your inquirer to know that the method we have been using very successfully



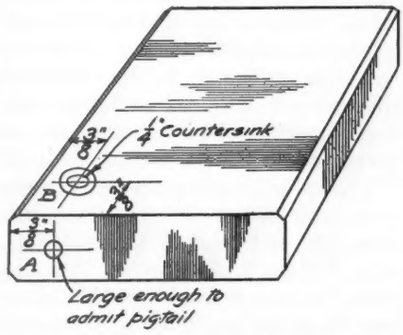
The Baylis method of attaching pig tail to carbon brush.

for the past 15 years or so consists in providing an accurately sized hole through the brush and inserting a tubular copper conductor with a spreader pin forced inside of it so as to produce an intimate contact between the outside surface of the copper braid and the inside surface of the hole. Unfortunately we do not have any catalog cut showing this construction, but it is very simple and the enclosed patent office drawing will illustrate it.

President, The Bayliss Company, Bloomfield, N. J. R. N. BAYLIS,

* * * *

In reply to the question by T. G. L. of Racine, Wis., in the July issue of INDUSTRIAL ENGINEER on connections for motor brushes, I have found the scheme shown in the accompanying sketch very successful. In making use of this method, tin the end of the pigtail and insert it in hole



Attaching pigtail to carbon brush

A, which is drilled through to hole B. Run solder with a soldering iron into hole B flush with the surface. The hole B should be drilled all the way through the carbon block and countersunk on both ends.

Macon, Ga. R. D. B.

* * * *

Armature Winding for D. C. Motors.—Please explain how the proper size and number of ampere turns of wire are computed for d. c. motors of 1, 5 and 10 hp. I have a faint idea that in a two-path armature winding the current carrying capacity of the wire is one-half the total ampere rating of the motor and for a four-path winding, one-quarter of the total. How are the ampere turns found?

New Britain, Conn. H. R.

The following formula and values will help to determine the size of wire and turns per coil for d. c. armatures: $E=(P\phi SZ)\div(60\times10^8\times M)$, where E equals the voltage developed in the armature, P the number of poles, ϕ the total flux per pole, S the r.p.m. Z the total number of face conductors equals (turns per coil $\times$ number of coils $\times$ 2), M

equals the number of paths in the armature.

For most cases E can be taken as the line voltage, S-P-M-E are known, Ø can be assumed and then Z can be found from the formula; Z equals $(E \times 60 \times 10^8 \times M) \div (\text{Ø} PS)$. Good values for Ø are, for cast iron pole pieces, 30,000 to 40,000 lines per square inch, and for wrought iron or steel laminated pole pieces, the density can be from 70,000 to 105,000 lines per square inch, then Ø equals the area of pole piece times flux density. The size of the wire depends upon the current flowing per path. This is equal to the full load ampere rating divided by the number of paths in the armature.

Then assume a value in circ. mils per ampere and multiply the current per path by this value. The results will be the area in circ. mils of the required wire. After the wire size and turns per coil have been determined, a slot full should be tried and, if possible, the wire size increased, as the more copper in the armature the cooler it will run and the overload capacity will by that means be increased.

The value for circ. mils per ampere run from 300 to 500 on small motors, 300 and below for fans ¼ hp., etc., 300 up to 500 for ¼ to 5 hp., then for larger machines the values run from 800 to 1200, the above values being correct to approximately 10 per cent.

Detroit, Mich. A. C. ROE.

* * * *

Winding for Bell Ringing Transformer. —Here is a question I would like to have answered by readers:

(1) What changes must be made in the winding of a 60-cycle bell ringing transformer for use on a 25-cycle circuit? The present winding is 1000 turns of No. 20 B & S and 100 turns of No. 14 wire. The rating is 100 watts, 110-volt primary, 10-volt secondary.

Brooklyn, N. Y. A. D.

In rewinding a transformer for the same voltage but for a different frequency from that for which it was designed, the new number of turns for the primary must be determined on a basis of keeping approximately the same flux density. With this condition the number of turns on the primary would have to be increased inversely as the change in frequency; that is, from 1,000 turns to 2,400 turns to operate on a 110-volt, 25-cycle circuit. It is evident that the number of turns must be increased in that proportion because the induced voltage per turn is reduced in the same ratio as the decrease in frequency, although the flux density is the same as before. Therefore, the number of turns must be increased so that the total induced voltage is 110 volts.

It is apparent that with a 140 per cent increase in the number of primary turns, the winding will require much more space than the 60-cycle one replaced. Therefore, it is desirable to reduce the turns to the lowest number consistent with the conditions of heating, etc. In transformer design practice the limits of flux density between which the iron is worked are pretty sharply defined for a given frequency. Because of the less heating at lower frequencies the density can be increased provided the exciting current does not become excessive.

On further analysis we find that the core loss at the lower frequency is but 35.55 per cent of its former value. This figure is calculated on the assumption that the ratio of hysteresis loss to eddy current loss is about 3 to 1. Since the hysteresis loss varies directly as the frequency with a given flux density, this portion of the core loss at 25 cycles is 25/60 or 41.6 per cent of its value at 60 cycles or 31 per cent (.75×41.6 per cent) of the total iron loss. The eddy current heating for any flux density is a function of the frequency squared so this part of the core loss is but 17.4 per cent $(25/60)^2$ of its initial value or 4.35 per cent (.25×17.4 per cent) of the total iron loss. Adding the new values of the two components of the core loss, the iron is absorbing only 35.55 per cent as much energy at 25 cycles as at 60 cycles while operating at the same flux density. It is seen then that there is a possibility of increasing the flux so that the iron loss may be made more nearly to approach its initial value.

In power transformer design the practice is usually followed of operating the iron at a density about 10 per cent higher for a 25-cycle than a 60-cycle machine. We might assume that the original transformer was operating on such a portion of the magnetization curve (70,000 lines per sq. in.), that this 10 per cent higher flux would result with about a 35 per cent increase in the exciting current. The number of turns would then be 10 per cent less than 2,400 or 2,160.

Even under these conditions the core loss would still be less than half its former value. This new figure (41 per cent) can be determined by working out the formulas for computing hysteresis and core losses.

The size of wire for the primary would probably have to be decreased from No. 20 to No. 23 so that the desired number of turns could be accommodated. By examining the no-load copper loss we find that the combination of a 35 per cent increase in exciting current and a winding with 2,160 turns of No. 23 wire replacing one of 1,000 turns of No. 20 wire has now increased this loss 686 per cent.

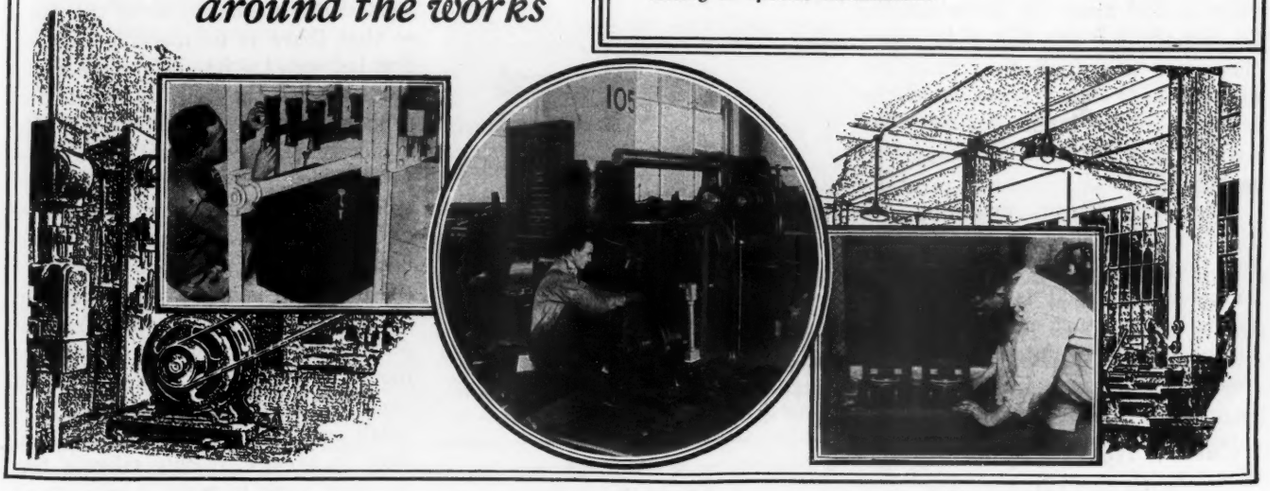
Although this figure as a percentage appears large its effect is almost negligible when applied to an I^2R loss that is itself practically insignificant. Assuming that the exciting current at 60 cycles was 5 per cent of the full load current and that the full load I^2R was equal to the core loss, it is figured that the heating caused by the exciting current was 0.125 per cent of the full load I^2R. It has now been increased so that it amounts to about 1 per cent (.125×7.86).

In rewinding the primary of the transformer with 2,160 turns of No. 23 wire we have reduced the core loss to 41 per cent of its initial value and increased the exciting current heating to 1 per cent of the full-load copper loss. Since the full-load values of both these losses were taken as 100 per cent, the no-load losses as a percentage of the full-load losses are 21 per cent. This figure corresponds to a little over 50 per cent for the 60-cycle instrument. Thus we have brought about a material reduction in the idling loss, a desirable characteristic in a transformer that is connected to the line 24 hours a day but may never be loaded more than several minutes during that time. The other dominating characteristic, that of full-load voltage, which would be slightly lowered if the instrument were rewound with the same ratio of transformation, can be had by using a few more turns than required by the old 10 to 1 ratio. It would also be necessary to decrease the size of the secondary wire from No. 14 to about No. 17 on account of space limitations. Thus it is seen that the characteristics of the transformer for bell-ringing purposes are improved, though its continuous capacity is less.

Chicago, Ill. D. F. HINE.

SERVICE
around the works

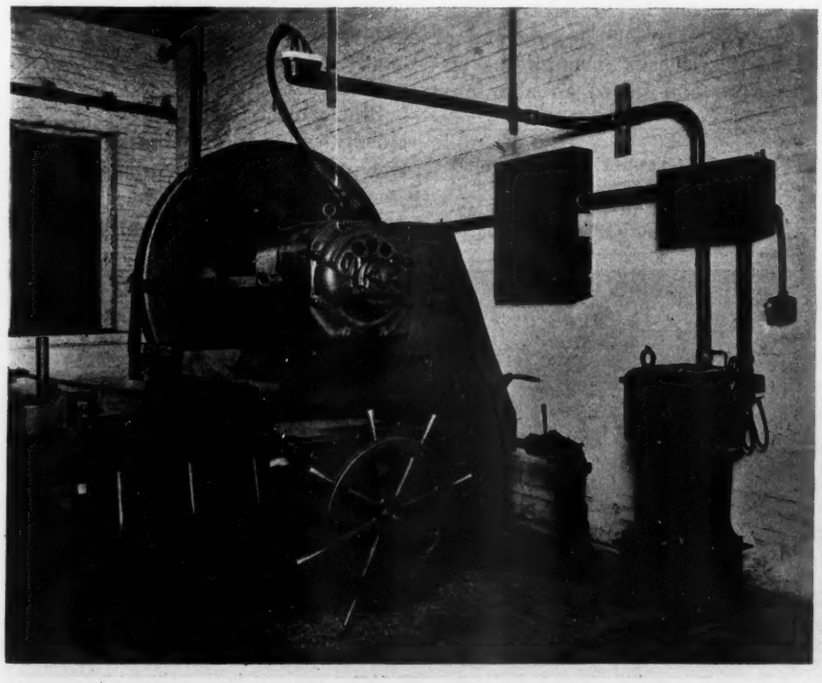
For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.



Automatic Compensator Limits Heavy Starting Current of Induction Motor

WHERE an induction motor is connected to a load that requires a long time to accelerate, there is danger in employing the ordinary manual starter. The operator cannot be relied upon to wait until the motor is up to the proper speed before he throws the starter to the "running" position. If the speed is too low an excessive current will be drawn. An automatic compensator which acts on the current-limit principle will, however, eliminate this chance of trouble. The compensator cannot be thrown over to the running position until the motor is running at the correct speed. Then, when it is thrown over, the current will not be too great.

An installation bringing out this feature was made recently in a Brooklyn warehouse for structural steel. In this warehouse a Ryerson high-speed friction saw was installed for cutting structural shapes. This machine is equipped with a 35-hp. squirrel-cage motor of special construction and carries on its shaft the cutting disk which is 48 in. in diameter and revolves at 1,700 r.p.m.



The automatic compensator limits the starting current of this motor which carries a load that takes a long time to accelerate.

It is always desirable to keep the starting current low, but in this case there was a certain definite limit set by the Brooklyn Edison Company which supplied this warehouse. In order to maintain good voltage regulation on its lines, this company has established a ruling that motors of over 15-hp. rating connected to its 220-volt, two-phase, four-wire, 60-cycle lines must not take over 5 amp. per horsepower per terminal during the starting period. The inertia to be overcome during the acceleration of the saw is very great and it was found impossible to keep the starting current within the prescribed limits of 175 amp. per phase when starting by means of a hand-operated starter which was of the primary-resistance type. The substitution of a hand-operated compensator was considered, but on account of the long starting period it was thought unlikely that the operator could be relied upon to wait the proper length of time before throwing the motor on to full line voltage. Therefore, an automatic compensator operating on the current-limit principle was installed.

This compensator transfers the motor connections automatically from the starting voltage to full line voltage when the motor current has been reduced by acceleration to a predetermined value. The operator

therefore has no control of the acceleration after he has pushed the starting button. The motor is connected to the 50 per cent tap on the autotransformer, and starts with an inrush of 150 amp. It takes exactly 58 seconds for the motor to reach the speed at which the transition automatically takes place from the starting to the running side. The current peak at transition is approximately 150 amp.

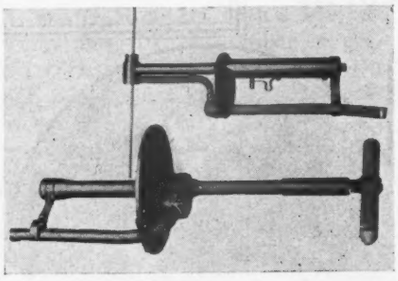
The compensator, made by the Electric Controller & Manufacturing Company, is of the totally oil-immersed type. It is controlled by means of a start and stop push-button station mounted on the wall.

New York City. E. H. H.

Cutting Heavy Copper Billets With the Electric Arc

ON ACCOUNT of the ductility of copper, it is difficult and expensive to cut, with hammers and chisels, the fins which form on the billets during the manufacturing process. These fins are often 1½ in. thick, several inches broad, and must be removed before the copper billet is made up into sheets, straps, tubes and other commercial shapes. Because of the great heat conductivity and thermal capacity of copper, tests were made to see if it could be raised by an arc to a sufficiently high temperature quickly enough to produce local fusion of the copper at the cut. These tests were first made on copper bars approximately 4½ in. square by 40 in. long. One of these was cut in two with a current of 900 amp. in about 7 min. actual cutting time. To get more nearly actual conditions, tests were continued on the large piece of copper slag shown in the accompanying illustration. This was approximately 7 ft. long by 6½ ft. wide and varied from 1½ in. to 7 in. in thickness. This piece of copper slag was cut in four strips, one cut through the center and thickest part and two other cuts along the edges of the piece where the copper was approximately 1½ in. thick. This thin section was cut at a speed of approximately 3½ ft. per hour with a current value of 1,000 amp. The central cut of 7 ft. was made in 5 hours actual cutting time, through an average thickness of approximately 4½ in., with a maximum of 7 in. at the center.

For this work the generator must be able to deliver not less than 1,000 amp. through the arc circuit. A panel, equipped with single pole switches connected in series with various groups of resistances through which the current value may be regulated to give the best results, is used to control the generator and stabilize the arc.

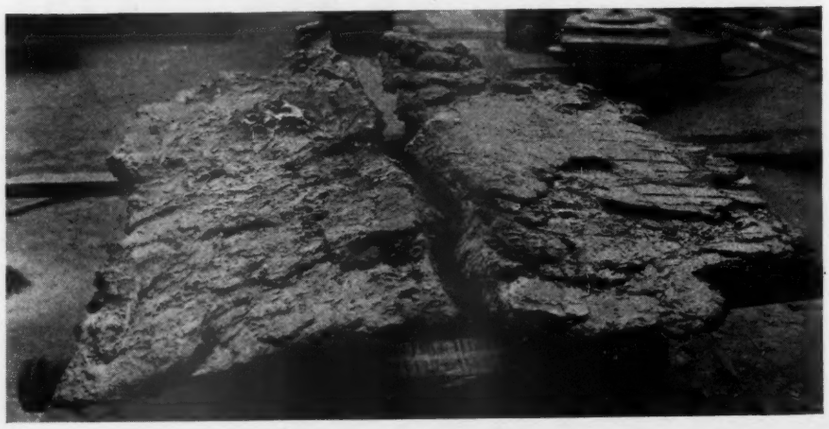


Here are two electrode holders made for heavy service. The upper one is designed for use with a metallic electrode and the lower one for a carbon electrode.

When carrying on cutting work at 1,000 amp., it is very essential that the operator have his body thoroughly protected by closely woven clothing, his hands by leather gloves, and the head and eyes by a suitable helmet. Among the most important items is providing an electrode holder which will have a sufficiently cool handle so that the operator can work continuously without experiencing discomfort in his hands. Such an electrode holder is illustrated in the smaller of the two accompanying illustrations. The cable carrying the current to the electrode proper does not pass through the handle, but is carried by means of a supporting lug at one end of the handle, passes through the circular disc, and up to an aluminum casting at the rear end of the electrode holder proper. This aluminum casting is mounted by a three-point crow's foot suspension on a micarta disc. Thus the handle is secured independently to the center of the disc, so that there is no metallic connection between the handle and the main portion of the electrode holder proper. By this construction the holder remains cool at all times. The jaws which grip the graphite electrode are formed from two pieces of cold-rolled steel. These are forced back into the open tubular end of the electrode holder proper and grip the graphite electrode by friction only. These jaws can be quickly removed by tapping alternately on each of them with light blows of a small hammer. If they become damaged in service, it only takes a few minutes' time to make a new set of jaws on a blacksmith's anvil or in an ordinary vise. A. M. CANDY.

Arc Welding Engineer,
Westinghouse Electric and Manufacturing Co.,
East Pittsburgh, Pa.

This piece of copper slag 7 ft. long and having an average thickness of 4½ in. was cut in two by an electric arc in approximately five hours.



Some Ways of Getting Rid of Static Electricity on Belts

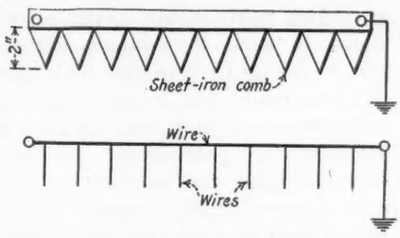
CONSIDERABLE annoyance is often caused by static electricity jumping from belts to surrounding parts, such as railings, pipes, iron beams, and so forth. When a person comes into contact with such parts it is quite annoying to receive a jolt, especially when one isn't looking for it. While in a sense this is not dangerous, still it is liable to cause trouble, inasmuch as the person receiving the shock may jump against some machine which is in motion and be injured.

Static electricity is generally decidedly worse in dry weather than in wet or damp, when it disappears or is considerably less. Belts running in an engine room or mill that is

warm all of the time are decidedly annoying, as they are not usually affected by the changes of the atmosphere and therefore the electricity is present at all times. While the following will not entirely cure the conditions, they will lessen them.

In order to relieve the dry condition, apply castor oil with a paint brush on the inside of the belt. If the oil is warmed slightly before applying it will penetrate the belt more readily. It will also make the belt more pliable and cause it to cling closer to the pulleys and carry its load better. If castor oil is not procurable, neatsfoot oil is equally good. Good results are also obtained by allowing the oil to run out of the can or bottle onto the inside of the belt in a small stream when the belt is in motion. Care must be taken not to apply too much at once, as it might make the belt slip.

The following methods may also be used with very good results: Make a comb out of sheet iron, the length equal to the width of the belt and about 3 in. wide. Cut teeth in it as in the drawing, making the teeth about 2 in. long. Suspend this over the belt, preferably on the tight



Here are two types of comb for draining static off a belt.

side and as close as possible without hitting. Run a wire from the comb to a good ground, such as a water pipe.

A bucksaw blade can likewise be used, with holes drilled to suspend it and for attaching the ground wire. In still another method, a wire is stretched horizontally 6 in. above the belt, with vertical wires hanging down every inch or so as near the belt as possible. It is also advisable to ground the frame of the engine and lineshaft to a water pipe or other ground, care being taken to see that all joints are clean and that all grounds make good contact.

Fairfield, Me. LEON L. POLLARD.

Size of Wire to Use for Protective Ground Connections

THERE does not appear to be a clear understanding among some electrical men as to the requirements for protective grounding, particularly the size of wire for the ground connection. The accompanying table lists the different systems and parts which are required to be grounded and gives the size of conductor either as required by the "Code" or as dictated by good practice.

As a rule, the weakest points in a ground connection are the contacts where wire connection is made to the part requiring the ground and to the part from which the ground is obtained. Care should be taken to see that sufficient contact area is obtained at these points.

The total resistance of a protective ground, if connection is obtained from an underground piping system, should not exceed three ohms and this value should not be exceeded for driven grounds when measured during a wet season. Driven ground connections measured during a dry period should not exceed a total resistance of twenty-five ohms. WILLIAM S. JONES.

Washington, D. C.

Size of Wires for Ground Connections

Purpose for Which Ground is Required	Size of wire B.&S.gauge		Remarks
	Min.	Max.	
Direct-Current Systems	8	No limit	Ground wire required to be 20% of capacity of the wire to be grounded.
Transformer Secondaries	8	1/0	
Steel Conduits and Armored Cables	10	4	The maximum size is required where the conductor contained in the conduit, armor or sheath is larger than No. 1/0 B. & S. Gauge.
Service Conduits	8	4	
Sheath of Lead-Covered Cables	10	4	
Frames of Equipment with 100-Amp. protection	10		This includes switchboard frame work, oil switch structures, outercasings of transformers, and frames of motors and generators.
" " " " 100 to 200 " "	6		
" " " " 201 to 500 " "	4		
" " " " above 500 " "	2		
Lighting Arresters	6	2	Minimum size for protection of individual equipment. Maximum for protection of systems.
Lightning Rods on Structures	2	4/0	Minimum size, 19 strands, to be used for buildings less than 60 feet high. Max. size, 61 strands, to be used for higher buildings and chimneys.
Radio Antenna	2		To be of a cross section having a periphery not less than .75 inch.
Radio Tower Steel Work	2		
Ground Detectors	14	10	Larger sizes to be used where not fully protected against mechanical injury.
Instrument Transformers	14	10	
Signalling Systems	14	10	

How to Take Care of Portable Meters

BECAUSE of their delicate construction, portable electric meters should be guarded against dropping, jar, or shock from pounding in their vicinity. Such abuse will dull the pivot-points, thus reducing the sensitiveness, and weakening the magnet, which will cause the instrument to read low.

Portable meters should always be used in a level position. An instrument should never be subjected to voltage or current too strong for it. This is likely to bend the pointer and cause error in readings, even if it does not burn the insulation of the coils. After measuring the voltage across the terminals of a motor field,

electro-magnet or other highly inductive circuit, the voltmeter should be disconnected before the main circuit is opened. Otherwise there will be an injurious rush of current through the meter, from the self-inductive "kick" at the opening of the circuit.

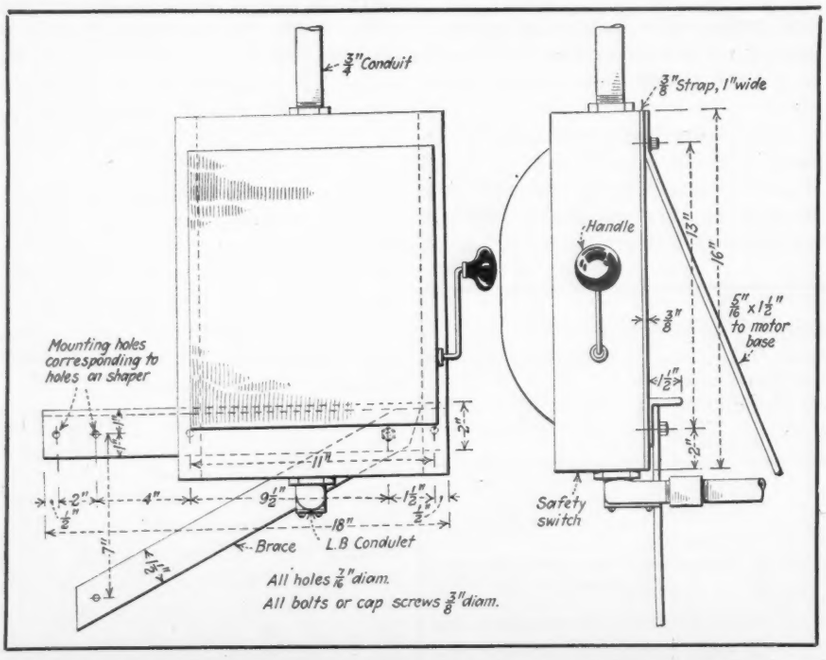
In cleaning a meter the glass may become electrically charged and by its attraction draw the pointer away from its true position. The glass should be discharged by pressing the hand upon it after cleaning. If the pointer touches the glass, or a bit of lint gets in the air-gap, or between the convolutions of the hair-spring, incorrect readings are likely to result. Care should be taken to keep meters away from conductors carrying heavy current, as the magnetic action of these is likely to affect the meter reading. Iron-filings or emery-wheel dust should never be allowed to come in contact with a direct-current instrument. This dust will eventually find its way into the meter case and work into the air-gap between the pole-pieces and iron core, clogging the moving coil. A direct-current meter should not be placed near iron or steel, as its magnet will be affected, causing error in reading. For the same reason two instruments having magnets, and in fact all meters, should be kept apart when in use. Setting a meter on a bench directly over an iron leg, or a drawer of tools, or on a concrete floor having concealed beams or rods of iron, will result in a low reading.

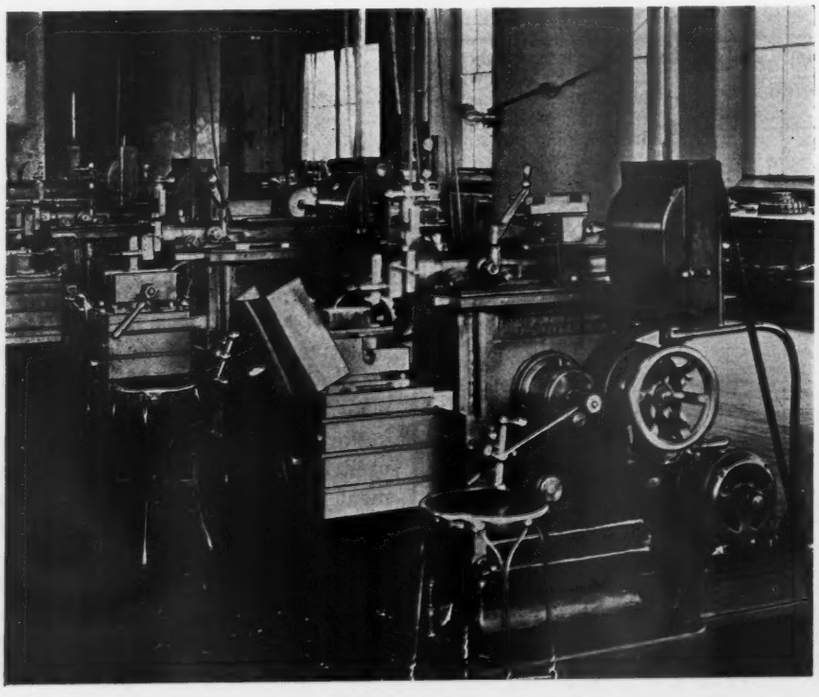
Ignition current from a coil or high-tension magneto should never be sent through a voltmeter. Dampness also is injurious, resulting in a high reading.

An ammeter with exterior shunt should always be connected to the shunt by the wires supplied with the instrument. The terminals of these wires should be clean and bright, and their connecting screws tightened firmly.

The pointer of an instrument should always come to zero when not in use—otherwise readings at all points of the scale will be in error.

Whitman, Mass. DEXTER W. ALLIS.





This motor starting switch is convenient, yet out of the way. The details of framework for mounting motor starting switch on shaper are shown above.

Motor Starting Switch Mounted at Rear of Motor-Driven Shaper

THE illustrations show a convenient method of mounting a Safety First double-throw motor starting switch at the rear of a shaper which is direct connected to a 3-hp. 3-phase, 60-cycle, 440-volt, 1,100 r.p.m. induction motor.

The mounting consists of a piece of 1½ in. by 2 in. by 3/16 in. angle iron 18 in. long, which is bolted to the frame of the shaper just under the traveler slides by two ⅜ in. cap bolts tapped into the frame. A piece of ¼ in. by ½ in. steel is bolted to the outer end of the angle iron and run on about a 20 deg. angle and bolted to the shaper. The switch is bolted to two pieces of ⅜ in. by 1 in. by 16 in. steel. A piece of 5/16 in. by 1½ in. steel runs from the top of the switch to the motor base.

The supply wires are run in conduit on the ceiling, tapped off in "T" condulets and dropped down in ¾ in. conduit to the top of the switch. Leads from the switch to the motor are run in ¾ in. conduit with an "L B 22" condulet at the switch and a "C 2" condulet with a 3-hole composition cover held in a condulet pedestal No. 23, which is bolted to the motor base. F. W. MCGRAW.

Swissvale, Pa.

How to Couple Bent Pipes in Out-of-the-Way Places

IN THE June issue of INDUSTRIAL ENGINEER, on page 299, Frank Harazim described a method of coupling bent pipes in out-of-the-way places. While his description and drawing are easily understood, I think I can make a suggestion that will improve the joint.

My suggestion is to first screw a locknut onto the pipe which has the long thread and then screw on the coupling. By using this method, after the pipes have been joined and the locknut screwed tight against the coupling after it has been screwed back to take the thread of the other side of the joint, the pipe will be as rigid as a joint made in the usual way.

This locknut will take care of any slight looseness in the joint due to the necessity of cutting an extra long thread on the pipe.

Alma, Mich. G. S. ROLF.

Signal System Used to Call Crane Operator

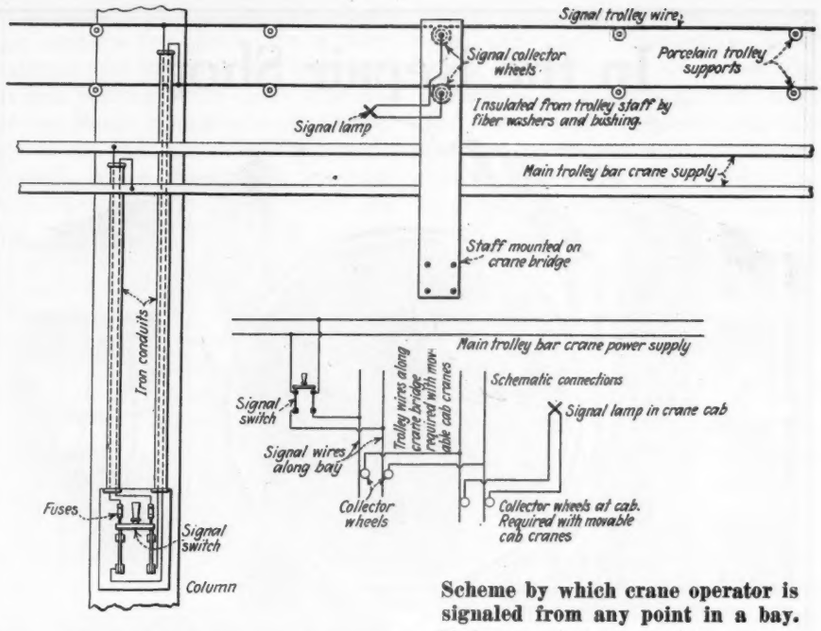
FOR SIGNALLING crane operators to let them know where their crane is needed, a simple but effective system is used in the plant of the Gary (Ind.) Screw and Bolt Company. In this system are a number of calling stations throughout a bay. When a workman needs the help of a crane he throws in a knife switch. This lights a lamp in the crane cab and signals the crane operator. The old practice was to go to the point where the crane was working and call the operator. Another plan was to hammer on a pipe or a sheet of iron or something similar, to attract the craneman's attention. Both of these schemes had very evident disadvantages which led to working out the present system.

In installing the new system a number of locations were selected for signal stations, as many as are required for the efficient operation of the bay. At each station a fused double-pole single-throw switch is installed. Two live lines come in conduit from the crane-trolley-bars to the signal-station switch fuses, thus bringing both polarities of the circuit through the fuses to the switch.

From the signal switch a circuit runs up in iron conduit to two signal trolley wires. These are of No. 9 iron wire stretched the entire length of crane travel from end to end of a bay, using a strain ball insulator and a long-thread eye-bolt at one end for tightening or slacking off to care for contraction or expansion of the iron wire. At the other end a strain insulator alone is sufficient.

At intermediate points are universal insulator supports holding ordinary porcelain knobs equally spaced throughout the bay length. The bare iron signal wire rests upon these knobs. Fastened to, and insulated from, the crane bridge are two trolley wheels which make contact with these wires, running along it the full length of the bay. These wheels are connected with a signal light unless the crane has a movable cab. In that case these trolley wheels are connected to two more trolley wires stretched the entire length of the crane bridge, one above the other. Along these bridge trolley wires also run two more trolley wheels which are in turn connected to the electric lamp placed in the crane cab. The bridge trolley wires and the second pair of trolley wheels are not required with stationary-cab cranes, but work very well with movable or swing-cab cranes.

If a workman upon the floor desires crane service he places the signal switch in the "on" position, lighting the signal lamp in the crane cab, without the noise which would attract every workman's attention thereabouts from his work, as was the case with the old system. The crane operator, upon seeing the lamp light, looks at his signal stations and if a workman is standing at a station with no one at other stations, the operator brings his crane to that station.


Signal trolley wire
Signal collector wheels
Porcelain trolley supports
Insulated from trolley staff by fiber washers and bushing.
Signal lamp
Main trolley bar crane supply
Staff mounted on crane bridge
Iron conduits
Main trolley bar crane power supply
Schematic connections
Signal switch
Trolley wires along crane bridge required with movable cab cranes
Signal lamp in crane cab
Signal wires along bay
Collector wheels
Collector wheels at cab. Required with movable cab cranes
Fuses
Signal switch
Column

Scheme by which crane operator is signaled from any point in a bay. If the crane cab is movable, two sets of trolley wires and wheels must be used, as shown in the lower diagram. One set of wires runs the length of the bay and the other set runs along the bridge across the bay. The signal lamp is in the cab. If the cab is not movable the second set of trolley wires is omitted.

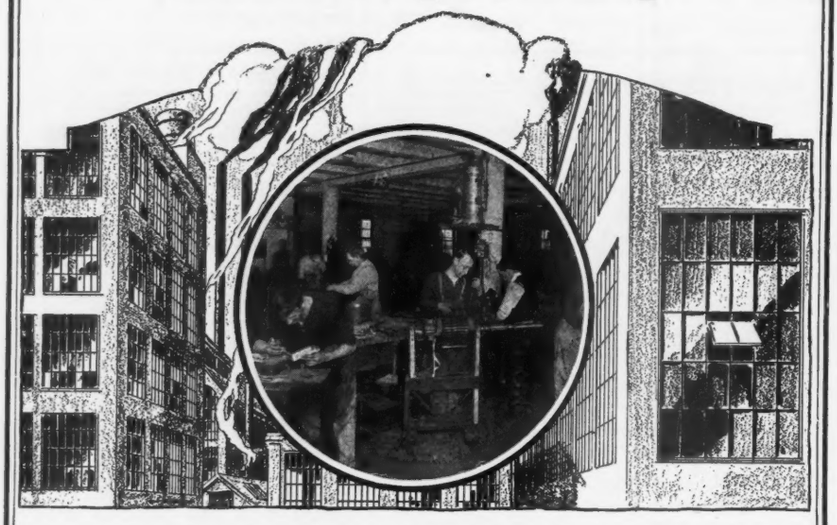
Whenever two or a dozen stations signal at the same time, the lamp will remain lighted until all have had the desired crane service. The crane operator sees that the signal switch is placed in the "off" position by a workman before leaving any department. He reports any carelessness of workmen concerning this to the chief electrician. Later the annunciator principle to indicate what station desires crane service may be tried.

A great advantage of this system is that the trolley wires are dead at all times except when a workman is signaling for crane service. It would be possible to rig up a signal system with only one trolley wheel, but this would maintain a "hot" circuit which would be dangerous and might in the end cost much more than the installation expense of the two-trolley-wire system.

This signal system is not by any means fool-proof. However, a little harmony between crane operators and workmen upon the floor will make it very effective. In practical application no trouble has been experienced so far. A. L. GEAR.

Gary Screw & Bolt Co., Gary, Ind.

In the Repair Shop



This section is devoted to all sorts of electrical repair work, large and small. Special attention is given to tools found convenient at the shop bench and short cuts or improved methods. Articles on these subjects are always welcome.

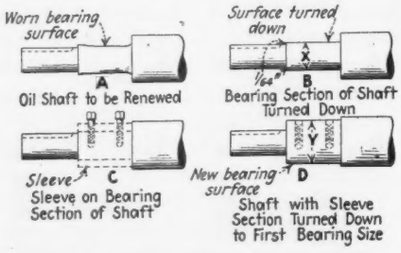
Seamless Steel Tube Used as Shaft Sleeve to Renew Wearing Section

IN CEMENT mills the bearings and shafts of motors are subject to abnormal wear on account of the great amount of dust that settles into the bearings. To meet this condition in an economical manner, the chief electrician of one large plant has adopted a set of standard bearing sizes together with a scheme of shaft renewals that has proven quite effective. The bearing diameters of the different standard sizes selected vary from each other by 1/16 in. This variation makes it possible to turn down a worn shaft to the next standard size without removing an excessive amount of stock. A new bearing of the same size as the turned shaft will always be found in stock ready to be mounted in place of the old one no longer serviceable with the shaft of reduced diameter.

When a new shaft has to be turned the first time it is cut down to a diameter about 1/32 in. larger than the pulley end and is then bushed up with a piece of seamless steel tubing. The tubing is pinned fast to the shaft in two to four places, using machine screws set in holes drilled and tapped through the sleeve and into the shaft. The screws are cut off flush and turned down with the tubing. As a rule, it is possible to select a tube that can be finished to a standard size and then later turned down three more times to a diameter 1/16 in. smaller than the previous finish.

After the original sleeve is completely worn and turned down it can be replaced with another. By following such a scheme it is possible to make up in advance a number of sets of bearings that will always be ready to use. A much smaller stock of bearings is required when definite shaft diameters are maintained in some such manner as this than when the successive turnings are made to random depths. By turning the shaft down to the limit the first time that it needs attention there is little chance that the future work will be irregular or vary from the established practices.

LaSalle, Ill. C. H. R.



Steps in the renewal of a worn armature shaft.

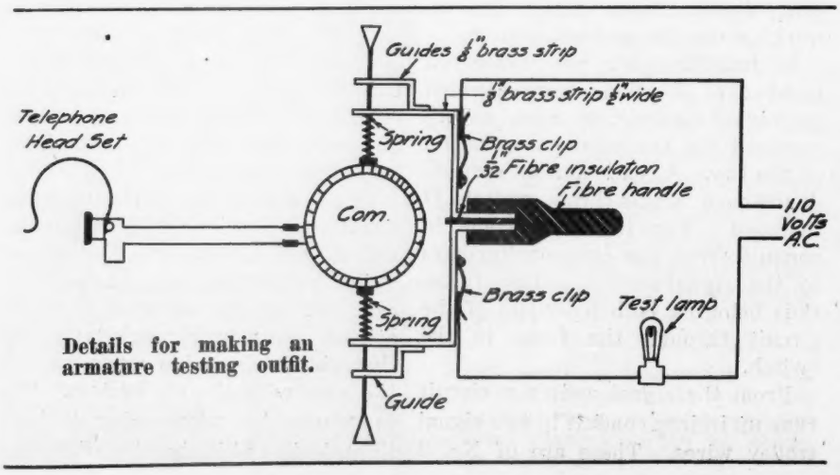
A The shaft end as it appears when taken out of service for refinishing.
B The irregular worn surface has been turned down to a size approximately 1/32 in. larger than the pulley stub. The diameter *X* should be such that some standard size of seamless steel tube can be finished on the inside to fit in the manner shown in *C*.
C Seamless steel tube pressed into place and fastened by two to four machine screws. Dotted lines show the tube.
D The sleeve has been turned down to a standard size and is ready for service. The new diameter *Y* is one of the shop standard sizes and may be reduced by 3/16 in. in three successive turnings before the sleeve has to be replaced.

Simple Device for Testing Armatures for Opens, Shorts and Grounds

THE accompanying drawing shows a device that the writer has made use of in testing armatures for opens, shorts and grounds when employing a telephone receiver. The device works very well for holding the test lamp to the commutator while making any of the above tests and it has occurred to me that it may be of interest to other readers of INDUSTRIAL ENGINEER.

The device can be easily made up from scrap brass strips, sheet fiber and a couple of springs, which material can be usually found around any repair shop.

When using the telephone receiver, as shown in the diagram, a low buzzing in the receiver indicates a good coil, when the receiver is held to adjacent bars between connections of



Details for making an armature testing outfit.

the test lamp which are placed on opposite sides of the commutator. A loud buzzing indicates an open circuit. No buzz at all indicates a shorted coil. RAY C. STANFORD.

Stanford Electric Repair Shop,
Chicago, Ill.

Convenient Work Bench Facilitates Winding of Small Armatures

FOR the efficient and rapid winding of small armatures it is advantageous to have a special bench on which to do the work. The accompanying illustration shows one of several benches installed in the armature winding department of the U. S. Auto Supply Company shops.

It has been found to be very useful in commercial work on small armatures. The armature-supporting centers are carried on a turntable so that the work may be turned to any position with ease. The top of the bench is large enough to hold all tools and materials ordinarily needed, while the drawer provides storage space for those which are not often required. If the drawer is provided with a lock, tools may be safely stored when the bench is out of service for a time. The bench is built of wood with the exception of the turntable, the winding centers and their supporting base, which are made of iron. Where armatures of only one size are handled the center supports may be made of wood and may be non-adjustable, but where shafts of various lengths must be handled it is best to secure a regular cast-iron center support with one adjustable end. A ball-bearing turntable support is used under the turntable shown, but a spindle of any convenient type mounted on the top of the bench will serve satisfactorily in most cases. The pipe carried at the top of the two standards at the back of the bench is provided to support the reel or reels from which the winding wire is taken. Reels of about 10-lb. capacity are most convenient, being light enough to be handled easily and still holding wire enough for several jobs. The lamp on the right-hand standard is connected in series with the lighting circuit and the coil of test leads shown on the top of the bench. The test leads serve as a convenient source of current for testing out the work as it progresses.

If you have to wind many armatures, why not make a bench like this?

A, adjustable center support for holding armature. *B*, lever for locking revolving center support base in any position. *C*, lamp in series with test leads. *D*, test leads on lighting circuit. *E*, trimming strip around bench. This projects a short distance above the top of the bench.

Chicago, Ill. C. H. R.

Changing a Two-Phase 2200-Volt Generator to Operate at Three-Phase 220 Volts

REWINDING a 2200-volt two-phase generator for 220 volts three-phase was a recent job accomplished under the writer's supervision. An industrial concern purchased this machine, a 120-kw., two-phase, 60-cycle, eight-pole, 900-r.p.m., 2200-volt, 226-amp., revolving-field generator, second-handed, and desired to reconnect it for 220 volts, three-phase, 60 cycles. A local repair shop reconnected the machine but it gave trouble, as coils burned out. The diagram shows the machine had 96 slots and 48 coils, one coil per slot, concentric-chain wound in two ranges, with sixteen groups of three coils per group, connected in series. Each coil had twelve turns of one No. 10 (B. & S.) double-cotton-covered wire, two wide by six deep, hand-wound.

It is obvious that the reconnection would not work, as there were six slots per pole per phase for a two-phase connection as shown in the full lines, three concentric coils forming each group. Then for three phases there would have to be two coils per pole per phase. This could not be obtained, as the two groups of three

concentric coils per group could not be divided into three groups of two coils each. Hence a 120-deg. spacing was not permitted by the physical arrangement of the coils.

It was decided, therefore, to rewind the motor. The opening in the top of the slot was found to be ⅛ in., and a good deal of slot room was taken up with insulation that would not be necessary for 220 volts. After checking the turns, size of wire, and so on, it was decided that a two-layer mush-coil winding could be developed that would be mechanically and electrically correct and still would be economical.

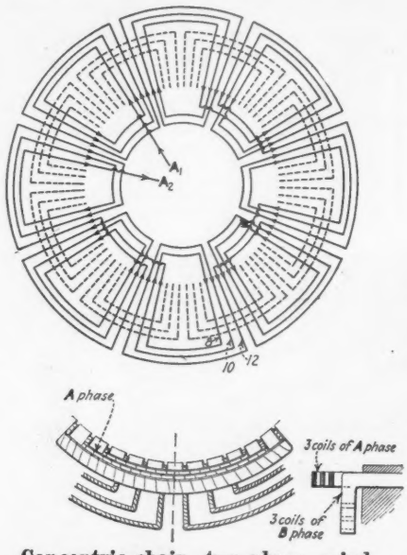
The 2200-volt, two-phase winding had forty-eight coils, or twenty-four per phase, in series. Then each coil developed 2200÷24=91.67 volts per coil. As each coil had twelve turns, one turn would develop 91.67÷12=7.64 volts per turn.

It was decided that a threaded-in type of winding could be developed and consequently a delta connection was desirable because it permits the use of smaller wire (a larger number of turns) than the star connection. Then for 220 volts per phase, the turns per phase for the three-phase winding would be 220÷7.64=28 turns. As the number of coils equals the number of slots in a two-layer winding, there would be 96÷3=32 coils per phase. But as only twenty-eight turns were required per phase, four slots per phase could be left empty. However, to make the machine carry more load it was decided to put in all the copper that could possibly fit in, as the generator would be overloaded intermittently. It was also requested, if possible, to arrange the connections so that the generator could be reconnected for 110 volts or 440 volts, three-phase. This would mean a **two-parallel or** four-parallel connection. The four-parallel was decided upon, as this made four paths for the current, hence a smaller wire in the coil.

Then for 220 volts, four parallel delta, there are 32÷4=8 coils per circuit that would have to develop 220 volts. If four turns per coil were used the machine would develop 7.64 ×4×8=244.5 volts. This would be all right, as the rating of the machine would be increased as desired; so four turns were used.

The 2200-volt two-phase coil pitch was 1 and 8, 1 and 10, and 1 and 12, as shown, or an average pitch of 1 and 10. The full pitch should be 96÷8=12, or 1 and 13. The short pitch was used, as it makes a shorter coil, requiring less end room and copper. The old winding had one No. 10 B. & S. wire to carry 22.6 amp. As one No. 10 wire has an area of 10,381 circ. mils, the circ. mils per ampere equals 10,381÷22.6, or 450.

The line current for the three-phase, 244-volt, 120-kw. rating is (0.578W)—(E×PF), where W= watts, E= line volts, and PF=power factor. Then assuming the three-phase power factor will be 0.83, an average value, the line current I=(0.578×120,000)÷(244×0.83)=343. For a delta connection the current per phase will be 343÷1.73=198 amp., or the current per coil, with a four-parallel connection, will be 198÷4=49.5, approximately 50 amp. Then with an allowance of 450 circ. mils per ampere, the three-phase 220-volt winding will require 450×50=22,500 circ. mils. The nearest size (B. & S.) wire, No. 7, has an area of 20,816 circ. mils.



Concentric-chain two-phase winding which was replaced by a three-phase winding.

This is an eight-pole, two-phase, series-connected, double-range winding. Full lines represent one phase. The other phase is partly shown by the dotted lines.

These sizes would carry the current, but the slot opening (with insulation in place) was only 3/32 in., so that No. 6 or No. 7 wire could not be threaded in, nor would wire so large make a good mush coil. Two No. 9 wires in parallel were still too large. Four No. 12 were next tried. One No. 12 equals 6,529 circ. mils and 4×6,529=26,116 circ. mils, which is sufficient capacity to carry the current. A bundle of thirty-two No. 12 double-cotton-covered wires was tried in the slot with a 0.023-in. fishpaper cell, and a 0.008-in. tan treated-cloth slider with a 0.023-in. fishpaper strip between top and bottom coils. A tan treated-cloth slider was used for the bottom coil. This was cut off and bent over, then the 0.023-in. fishpaper strip was put in with a tan treated-cloth slider for the top coil. After the top coil was inserted the slider was cut and turned over, and a 1/6-in. fiber wedge driven in. In this trial the No. 12 wire was rather tight to force through the slot opening, but a No. 13 went through nicely. Five No. 13 gives 5×5,178=25,890 circ. mils, which is large enough to carry the current. Therefore a bundle of forty No. 13 single-cotton-and-enamel-covered wires were next tried in the slot, insulated as above. These were satisfactory.

Accordingly, ninety-six flat diamond mush coils were wound with four turns of five No. 13 single-cotton-and-enamel wires in parallel, with a pitch of 1 and 10. The 0.023-in. fishpaper slot cells were made 2 in. longer than the iron, i. e., to project 1 in. either side of the core. The coil ends were taped with 0.007-in. by ¾-in. cotton tape, half-lapped. The tape was started on the bottom cell section, extending into the fishpaper cell ½ in. on each end, and ending about 2 in. away from the top cell. As each top cell was put in, it was wedged in place and the untaped section was taped by the winder. This tape was used also to seal the ends of the cells by wrapping it around the wedges and up to the core. The beginning and ending of each pole-phase group was taped with one half-lapped layer of 1-in. by 0.008-in. tan bias-cut treated-cloth tape. The machine was connected four-parallel delta for 220 volts, three-phase, eight poles, 120 kw.

With 25,890 circ. mils and at the rate of 450 circ. mils per ampere, each coil would carry 25,890÷450=57.75 amp. Then 4×57.75=231 amp. per phase and the line current is 231×1.73=399.6 amp. Then with 220 volts and 399.6 amp. per line and a power factor of 0.83 the machine would be good for a rating of (220×1.73×399.6×0.83)÷1,000=126 kw., approximately.

The machine was wound as described and connected four-parallel delta for 220 volts. If it is necessary to operate on 110 volts, an eight-parallel delta connection can be made or a two-parallel delta for 440 volts.

Detroit, Mich. A. C. ROE.

Handling Materials

Better ways to transport and handle raw and finished parts in and around the works will be discussed in this section.

Investigations of Routine Material Handling in an Old Plant Preliminary to Installing Electric Trucks

WHEN considering the installation of electric industrial trucks in any plant it is worth while to investigate the amount of handling, the routes covered and the general conditions under which the work must be done before deciding on the type of truck or tractor to install. Some of the investigations made at the plant of the Dodge Manufacturing Company, as outlined in the Aug. 10 issue of the *American Machinist*, are summarized here.

The plant in which it was decided to use electric trucks consists of good-sized machine-, floor- and bench-work foundries; machine shop and erection floors for the larger class of work; a large section devoted to wooden articles; a sheet metal shop, sawmill and several departments devoted to the smaller lines of both stock and made-to-order machine work. All of these departments, together with such accessory departments as power, tool, inspection and warehouses, are spread over a space of several acres.

The products consist of a large variety of parts, both metal and wood, ranging in weight from an ounce or so to several tons. A large amount of the output consists of stock items, but there is also a considerable output of made-to-order goods.

It was this varying nature of output handled, together with the nature of roads to be traveled, that had made it *seem* uneconomical to consider other than the hand-propelled balanced truck for the moving of material. Finally a more complete survey of the actual conditions was made than had yet been attempted. This included routes regularly traveled, average trips per day over each of these routes under normal production conditions, average number of men necessary per trip on hand trucks, average time per trip, in fact as detailed a record as possible of all factors entering into the shop transportation system at that time. Table I is a summary of the results of these tests.

This investigation proved that there was a large amount of soldiering and unnecessary time lost on each trip over all of the routes and that, pending the installation of mechanical handling, it was easy to place a time limit on the routes and by means of a rough check on the trips, cut down the actual trucking time considerably. Correspondence with a number of makers of industrial electric trucks estimated the operating cost of various types of electric trucks, including depreciation, upkeep, current, operator, interest on investment, etc., as in Table II.

Considerable trouble was experienced with the charging outfit, owing to the fact that the factory uses direct current of high voltage, available only at certain hours during the day, while the charging voltage on batteries is low and should be continuous over a period ordinarily counted as idle shop time. Ultimately a small motor-generator set actuated by standard city current, which is available at all hours, was installed to handle the charging.

Hydrometer readings of the battery are taken morning, noon and night, together with a record of the current consumption for the day up to that hour, as shown by the ampere meter mounted on the truck. This close supervision has kept the storage battery in first-class shape.

The heaviest routine loads are from the various metal-working de-

Summary of Routine Trucking

Route No.	One-man Time, Min.	Average Daily Trips Single	Average Daily Trips Double	Total Daily Time	Total Daily Cost
1	25	0	10.5	262	$ 1.31
2	35	16.6	5.3	600	3.00
3	45	2.2	9.4	489	2.44
4	30	27	7	616	3.08
5	50	0	43	2,150	10.80
6	40	0	22	880	4.03
7	46	0	6.5	300	1.50
8	40	0	11	440	1.83
Total daily cost					$27.99

Table I—How material "flows" in one plant.

This is a summary of an investigation made to determine the practicability of electric trucks. This covers merely the common routine jobs, in addition to which there are a large number of regular moves, which are made at longer intervals, together with special jobs of transfer, switching of cars, etc., which are not taken into consideration at this time. Some jobs are, of course, never put into the routine and require hand work.

Cost of Electric Trucks

Initial Expense	
Truck	$2,000.00
Skids, trailers, etc.	200.00
Charging equipment	400.00
Total	$2,600.00
Annual Expense	
Depreciation on 5-year basis	$520.00
Interest at 7 per cent	182.00
Allowance for upkeep	100.00
Total annual charge	$802.00
Daily Operating Expense	
Daily charge of 300-day basis	$2.67
Daily cost, operator, 9 hrs. at 50c.	4.50
Current cost	.50
Total daily cost	$7.67

Table II—A preliminary estimate of truck operation costs.

Before deciding on making the change, this estimate of the cost of operating the equipment was compared with Table 1, which shows a difference of approximately $20 a day if only one man and truck would be necessary to do the equivalent work. Actual operating cost may be a little more or less, according to a change of any of these items.

partments to the small-parts inspection, which is located on the second floor of the warehouse and shipping building and is reached by a steam-hydraulic elevator from the entrance to the first floor placed several feet above ground level. As a result, all trucks that enter this floor must negotiate a ramp with a grade of about 14 deg. and perhaps 40 ft. long.

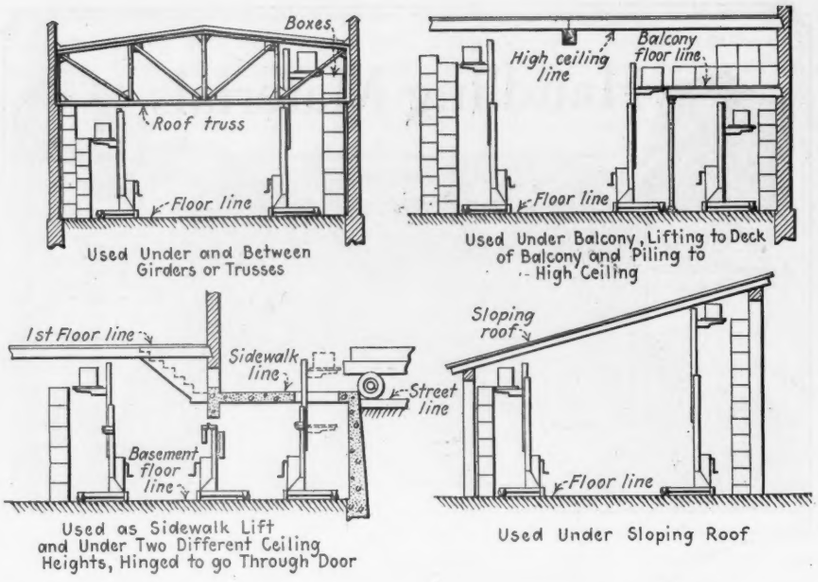
In spite of a preference for a certain type of battery through a belief in its ability to best withstand general abuse in the hands of unskilled operators, this one troublesome incline finally made it necessary to give ground in favor of a battery of another type which, through its greater ability to meet sudden increases in unloading rates without permanent injury, met the requirements.

Manager of Production,
Dodge Manufacturing Co.,
Mishawaka, Ind.
D. WRIGHT.

Widening the Use of Tiering and Piling Machines by Telescoping Frame

IN PILING or tiering boxes or other objects, one of the principal difficulties is that if they are piled close to the ceiling it is difficult to get at the lower boxes without tearing down a high tier. Sometimes, too, the boxes or crates are not substantial enough for the lower rows to hold up the weight of the others if the pile is very high. This is overcome by placing along the wall a balcony or shelf which divides the total height in two. This, however, formerly required hand piling either under or on the balcony or a high and a low tiering machine, as the machines were of a fixed height.

Now, however, by using the Economy tiering machine with a telescopic frame the same equipment can be used either underneath or above the balcony as is shown in the two accompanying illustrations. Here a tiering machine of 750 lbs. capacity is fitted with a 1/3-hp. electric motor which is operated from a light socket, at 110 volts alternating current in this case. The motor is started and stopped by a snap switch which is shown connected to a fuse box attached to the frame of the machine at the left. The motor is connected to the lifting mechanism by a chain drive. This machine may be operated by a crank if necessary.

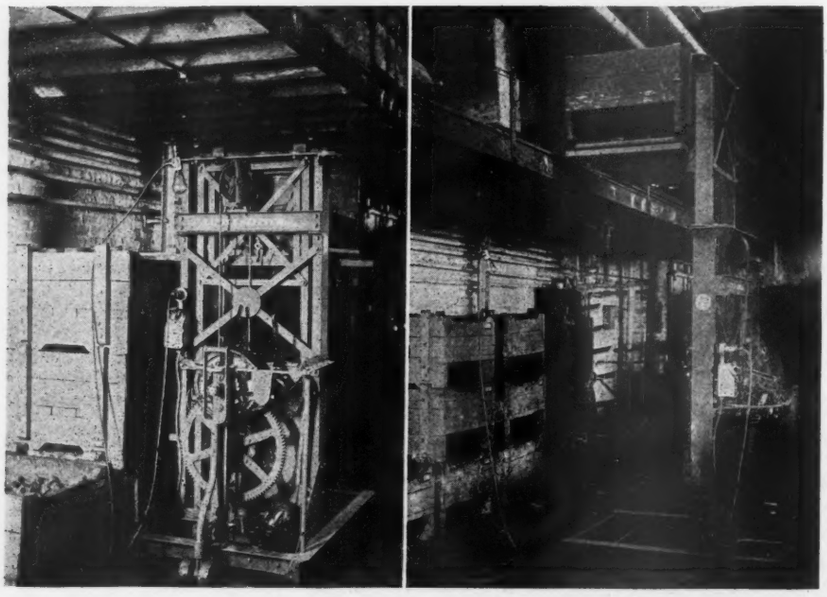

Boxes
Roof truss
Floor line
Used Under and Between Girders or Trusses
High ceiling line
Balcony floor line
Floor line
Used Under Balcony, Lifting to Deck of Balcony and Piling to High Ceiling
1st Floor line
Sidewalk line
Street line
Basement floor line
Used as Sidewalk Lift and Under Two Different Ceiling Heights, Hinged to go Through Door
Sloping roof
Floor line
Used Under Sloping Roof

Telescopic frame on tiering machine facilitates use of all odd corners for storage.

Many times buildings are so constructed as to have out-of-the-way corners which are difficult of access. Several places of this type and how they can be used are shown in this sketch which is practically self-explanatory. In any case the use of these tiering machines in such places does not prevent their employment wherever desired.

Piling underneath and on top of a balcony.

Stock is stored by piling these tote-boxes in which the parts come from the machines. When wanted it is taken from the pile by the tiering machine and carried to the assembly floor on a lift truck. This machine is either power or hand driven and gets its current from a lamp socket. Machines of over 1,000 lbs. capacity must, however, tap a power line. Rollers on the platform make it easier to load or unload the boxes or to connect up with a coveyor system.



When it was necessary to make a low machine which would pass through a doorway the machines were formerly hinged so that the top part was laid back. Loads, however, could not be elevated while the top was down. By telescoping—one frame is made to slide inside the other—any variations in height between the minimum and maximum may be obtained. In operating this tiering machine the platform is first elevated to its full height and then the inner or telescoping section raises, carrying with it the platform and load as shown.

By using these sectional and portable tote boxes as shown here to store parts a large amount of labor is saved in handling, as it is not necessary to put them into fixed storage and then take them out of storage again when ready to use. Now

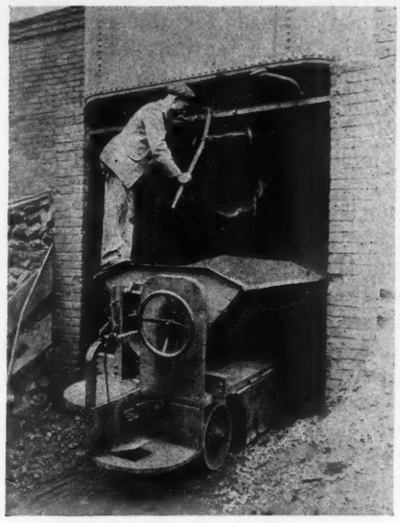
the tote boxes are set on the floor and carried by lift trucks directly to where they are to be used, thus saving two handlings by hand.

Some of the other uses which may be made of this telescopic tiering machine are shown in the accompanying sketch. These machines are made by the Economy Engineering Company, Chicago, Illinois, and the pictures were taken of the use this company makes of them in its own stockroom.

Dump Body on Electric Storage Battery Truck Cuts Cost by Half

FOR handling coal, ashes and other similar service a special body is often necessary or at least can be used to good advantage. For example, at the C. H. Marland & Son carpet factory, Philadelphia, Pa., a Lakewood storage battery truck fitted with a V-dump body of one-yard capacity has cut 50 per cent from the cost of handling coal to the boiler house and storage. The same truck is used to handle ashes.

The coal is unloaded from the cars into a bin storage which is high enough to load the coal by gravity from the bin by opening a "gate" as is shown at the left in the accompanying illustrations. The truck is loaded in 8 sec. while it formerly required 5 min. to load it by hand. During the morning the operator hauls enough coal in 2 hours to keep the boilers going all day. Ashes are then taken from the overhead ash-storage to the dump. Time is saved here in loading by gravity through a gate, the same as in handling the coal. This is illustrated in the smaller of the three photographs.



Coal and ashes are handled at a saving of approximately 50 per cent over the former method.

With this one-yard V-dump body placed on a storage battery truck platform one operator can handle about twenty tons of coal per hour. The time of loading alone is cut to less than 3 per cent by the quick loading method explained and illustrated here. Sand, gravel, refuse, mixed concrete, or any loose material which can be dumped may be handled with practically as large savings as were made here in moving coal or ashes.

A large amount of coal is put in storage and all of it is piled by this truck. The storage yard is about 115 ft. from the bins and the operator makes a round trip in 90 sec.: out, loaded, in 45 sec., dump in 10 sec., and back empty in 35 sec. It is necessary to provide a track or roadway for the truck so that it can climb the pile of loose coal. For this a portable track is used which is made from plank and is sectional. Each section is made by nailing 2-in. by 10-in. planks flat to cross pieces so as to form two runways the right distance apart for the truck wheels. A 2-in. by 4-in. plank is nailed edgewise along the outer edge of the flat planks to form a guide-rail which prevents the truck from running off the planks. Coal is dumped on either side and when necessary to pile wider or build higher the runway is raised or moved. The four-wheel drive of the Lakewood truck enables it to make the 10 per cent grades easily. A large gang of men with wheelbarrows would be required to move coal to storage at the rate of 20 tons per hour as is done by the truck.

It is estimated that interest charges, depreciation, repair labor and material, tires, oil and grease, and so on, would cost approximately $2 per day per truck. The depreciation, interest, renewals, and the like, of the storage battery would add another dollar per day. The cost of electricity is low and would run for practically continuous operation about 35 to 40 cents per day. This would make a total daily operating cost of less than $3.50 plus the time of the operator on an hour basis. The saving of one man would pay for this. The truck was made by The Lakewood Engineering Company, Cleveland, Ohio.

Size of Fuses for Motors

(*Continued from page* 419)

duty were much heavier than this, a larger fuse would be required.

Motors over 5-hp. use compensators to reduce the excessive starting current. The current in the line is then directly proportional to the square of the percentage tap. On the assumption that the 80 per cent tap is used and that the effective value of the starting current without compensator would be 7 times full-load current, the line current can be taken at about 4.5 times full-load current. A 50-hp., 220-volt, 3-phase motor having a normal current of 125 amp. starting from the 80 per cent tap of the compensator would require a current during the starting period of 562 amp. If the motor attains full speed within a period of 30 sec. the 30-sec. curve in Fig. 1 shows that a 220-amp. fuse will carry the starting current.

From the above, it is evident that the time curves in Fig. 1 may be applied to any specific case. If average conditions are assumed over a range of motor capacities it is possible to deduce simple and convenient formulæ which can be applied in practice. For example, it is required to obtain formulæ for the calculation of the starting fuse necessary for single motor installations operating at 220 volts, 3-phase. Assuming an average current of 2.5 amp. per horsepower and connections made to the 80 per cent tap of the compensator (giving a line current equal to 4.5 times full-load current) with a maximum starting period of 30 seconds, equation (1) reduces to:

(3) $I_t=4$ (hp.+6).

If a greater factor of safety is desired, the 60-second curve may be taken and the following obtained from equation (2):

(4) $I_t=4.5$ (hp.+5.5).

For 440-volt motors, equations (1) and (2) reduce to:

(5) $I_t=2$ (hp.+12), for 30-seconds starting period.

(6) $I_t=2.25$ (hp.+11), for 60-seconds starting period.

For group motor installations, simple formulæ may also be deduced. Assuming the largest motor in the group is starting and the remaining motors operating at full load, we obtain equations (7) and (8) on the basis of a 60-second starting interval. The 60-second interval is recommended for general use because of the slightly reduced time limit for fuses carrying partial load.

(7) $I_t=4.5$ ($P'+0.22$ $P+5.5$), for 220-volt, 3-phase.

(8) $I_t=2.25$ ($P'+0.22$ $P+11$), for 440-volt, 3-phase.

Where $P'=$ hp. capacity of largest motor in group and $P=$sum of hp. capacities of remaining motors.

The curves shown in Fig. 2 are based on equation 7. Similar curves could be obtained for 440-volt motors by plotting equation 8.

For a group of 220-volt, 3-phase motors consisting of one 40-hp. and two 10-hp. motors, equation 7, or reference to the curves in Fig. 2, would indicate that a 225-amp. fuse will be sufficient. The size of conductor used in this feeder would be determined on a basis of 110 per cent current for the 40-hp. motor, plus normal current for the remaining motors, giving a total load of 160 amp., indicating a No. 3/0 wire. The National Code does not permit it, but it seems reasonable to fuse this conductor to 225 amp.

It is interesting to know the relation between the horsepower capacity of the largest motor in the group and the sum of the horsepower capacities of the remaining motors when feeder fuses rated in accordance with Table *A* will just absorb the starting current. This can be determined for 220-volt, 3-phase motors by solving the equation:

4.5 ($P'+0.22$ $P+5.5$)$=2.5$ ($P'+P$)

whence $P'=0.75$ $P-12.5$.

For example, assume P equal 100 hp., then P' would be limited to 62.5 hp. if feeder fuses rated in accordance with Table *A* are to carry the starting current of the largest motor when the remaining motors are carrying full load.

The above formulæ for group motor installations are based upon the arithmetical sum of the starting and load currents. On account of the low power factor during the starting period, there is considerable phase displacement between the starting and load currents and consequently the vector sum or the true value of the total load current in the feeder is less than the arithmetical sum. The difference, however, is slight and the latter gives a greater safety factor.

In Fig. 3 there are given straight line curves which will be found useful in determining the size of fuse and size of conductor required in group installations of 220-volt and 440-volt, 3-phase induction motors.

Troubles in D. C. Armatures

(*Continued from page* 441)

about eight commutator bars, which is one-fourth of a bar less than one-quarter of the total number. Neglecting the fraction of a bar, the start of the coil is connected four bars to the right of the line drawn straight out from the left-hand side of the coil, and the finish of the coil connected to the bar next to it.

We will for the second example locate the first coil connection to the commutator of an armature with the brushes resting on the commutator midway between the pole tips as illustrated in *D*, Fig. 5. In this case the leads are brought straight out from one coil side as at "*A*" in Fig. 1 (*D* and *E*). Then the first coil connection to the commutator would be located by drawing a line through the center of the side of the coil at which the leads are brought out to a mica segment between two commutator bars calling the bar on one side of the segment No. 1 and the bar on the other side No. 2 as in the other illustration, where the brushes were on a line with the center of the field poles and the leads were brought out at the center of the coils.

It can be very easily seen why the brushes on some motors or generators are between the pole tips or on a line with the center of the poles by inspecting the housing. For instance, on some vehicle motors, enclosed motors and other motors, the brushes are accessible only from a certain point at a small opening in the housing opposite the brushes.

The foregoing are the tests which can be used to locate troubles while putting the coils in place. There are other troubles which can be located only after the leads have been connected to the commutator. The other common faults that are likely to develop while winding the armature are as follows: While placing a coil in the slots, the insulation on two or more of the turns of wire might be damaged which would allow the bare wires to touch each other thereby producing a short circuit in the coil itself. One or more coils may be cross-connected to the mutator in a reversed direction or coils may be cross-connected to the commutator. A later article will tell how to test for and remedy these troubles.

Ball and Roller Bearings

(*Continued from page* 429)

where they must fit having previously been taken up by the oil well. The babbitt used for this purpose must contain 8 to 10 per cent of antimony; this amount of antimony makes it nearly as hard as cast iron.

To fill with babbitt, the end shield is set flat on the floor with the housing end up; two wooden caps are then inserted into the housing, one from the bottom and one from the top, to fill entirely the space which will be occupied by the end caps and the bearing, as well as the space left for grease. An opening is left in the top cap to pour in the babbitt. When thus poured in, the babbitt will form a good, solid support which will easily hold up both the bearing and the end caps. The caps and housing are then bored for ⅜-in. machine bolts, as shown in the drawing on page 429.

Next comes the work on the rotor shaft, which has to be cut down and turned to take the ball bearings. To find the point at which to cut down the shaft, both ball bearings are inserted in their housings and placed in the position which they will occupy when running; that is, with the center line of the bearing in the center of the housing. The center line of the stator is then marked on the laminations and the end shields are fastened in place with the rotor left out. It is then easy, by using the combination square and rule, to find the distances of the inside of each bearing from the center line of the stator. The center line of the rotor laminations is then marked on the rotor and, as that must coincide with the center line of the stator, the point at which to cut down the shaft, for the inside of the bearings, is easily located.

Although the ball bearing is always chosen of such size that the diameter of the inside race is a little less than the diameter of the shaft, in most cases a sleeve has to be turned and pressed onto the shaft so as to give a shoulder against which the inside race may bear. The sleeve should be thick enough to give as wide a shoulder as possible without binding against the balls.

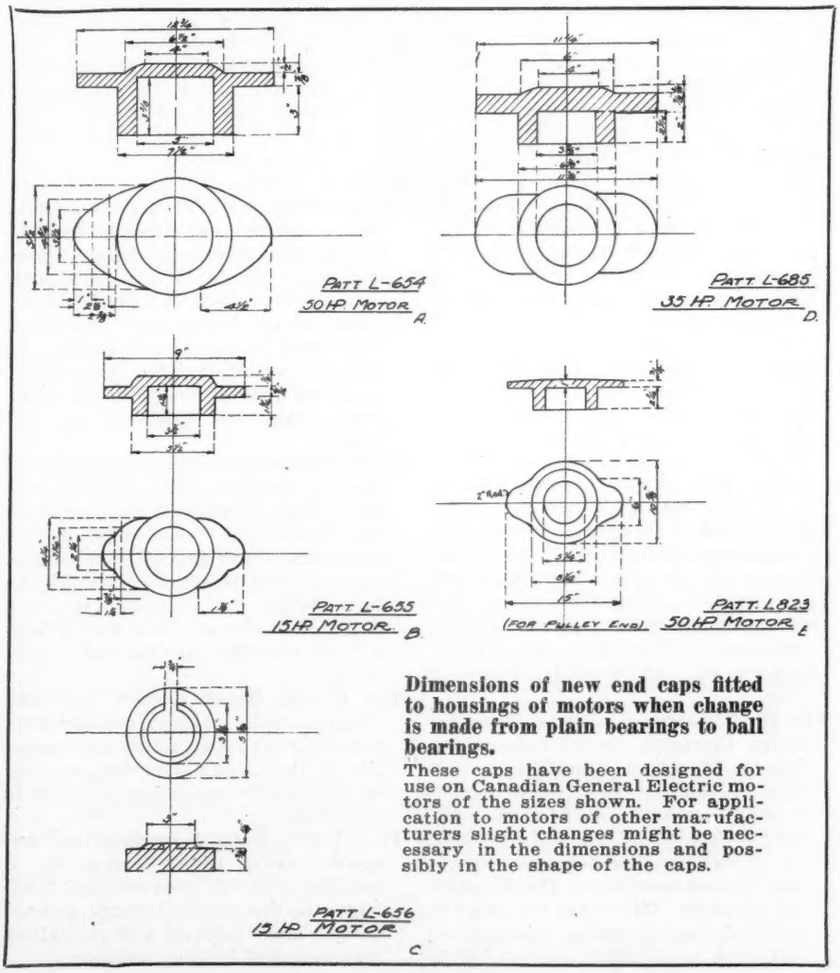
The same applies to the ½-in. thick octagonal nut which is placed on the outside of the inner race to hold it in position and is held by a ¼-in. by ½-in. set screw, a simple method which has been found quite satisfactory. This nut, which has ten threads to the inch, is octagonal in shape in order that it may be as thick and strong as possible.

The shaft has to be turned to a tight press fit for the inner race; for shafts up to 2 in., from 0.0002 in. to 0.0005 in. is allowed for clearance; for shafts from 2 in. to 4 in., 0.0005 in. to 0.001 in. clearance is provided.

The outside caps are bored and threaded for ¼-in. pipe plugs, so that a grease gun can be used to put in fresh grease. This company has found that No. 1 Keystone grease gives good results.

Data Sheet for Fitting Canadian General Electric Motors With Ball Bearings

Pattern No.	Horse Power	Speed, R. P. M.	S. K. F. Bearing
L-656	10 15	900 1200	1309 1309
L-655	15	900	1311
L-685 L-685 L-685	25 35 35	600 720 900	1312 1312 1312
L-654 L-654 L-654	35 50 50	600 900 600 Outside end only	1314 1314 1314
L-823	50	600 Pulley end only	1316



Dimensions of new end caps fitted to housings of motors when change is made from plain bearings to ball bearings.

These caps have been designed for use on Canadian General Electric motors of the sizes shown. For application to motors of other manufacturers slight changes might be necessary in the dimensions and possibly in the shape of the caps.

One point which Mr. Gallant emphasizes is that the outside race must be left free to move endways, about ⅛ in. being allowed between the bearing and the end caps. This also helps to make the rotors interchangeable, as it allows for slight differences in the width of rotors and stators. End caps for larger size motors have lugs at the sides through which the holes are bored for the bolts to hold them in place.

There are many designs of ball bearings to meet various conditions of service; consequently when motors or machines are to be changed from plain to ball bearings it is advisable to obtain the recommendations of the manufacturer, and avoid the possibility of costly mistakes.

(Acknowledgment is made to the following concerns for assistance in securing information and illustrations: American Roller Bearing Co., Pittsburgh, Pa.; Auburn Ball Bearing Co., Rochester, N. Y.; Bower Roller Bearing Co., Detroit, Mich.; Chicago Pulley & Shafting Co., Chicago, Ill.; Fafnir Bearing Co., New Britain, Conn.; Hyatt Roller Bearing Co., Harrison, N. J.; Nice Ball Bearing Co., Philadelphia, Pa.; Norma Company of America, Long Island City, N. Y.; Schatz Manufacturing Co., Poughkeepsie, N. Y.; S. K. F. Industries, Inc., New York, N. Y.; The Ball and Roller Bearing Co., Danbury, Conn.; The New Departure Manufacturing Co., Bristol, Conn.—EDITOR.)

Trade Literature
you should know about

The Edward E. Early Company, Canton, Ohio—The use of Early's commutator cement for repairing pitted armature segments and other crevices in commutators is explained in a small circular. With this it is claimed that defects which cause heavy sparking and might result in a burnout if not taken care of can be repaired with only a ten-minute shutdown.

Joseph Weidenhoff, 4352-8 Roosevelt Road, Chicago, Ill.—A small booklet entitled, "Keeping Up With the Profession," gives a description of the line of Weidenhoff testing equipment, which has wide application even though much of it was designed for automotive battery and electric service station work.

Wright Manufacturing Company, Lisbon, Ohio—Hoist catalog No. 19 shows the construction and application of the various types of Wright high-speed and standard hoists and differential chain blocks, ranging from ¼ to 30 tons capacity.

Leland Electric Company, Dayton, Ohio—Announcement is made of a new line of ⅛ to ¾ hp. motors of odd frequencies and direct current type in interchangeable frames. Special attention is devoted to single-phase motors of the repulsion-induction type.

The Westinghouse Electric & Manufacturing Company, East Pittsburg, Pa. Recent literature describes a new type of compact and rugged direct-reading, portable ammeters and voltmeters, known as type PX-3 meters, for general testing purposes. These instruments operate on the D'Arsonval principle. The cases are made of moulded, acid-resisting composition and so are especially serviceable in battery testing and some types of industrial work.

Karos Electric Company, 217 West Illinois Street, Chicago, Ill.—A small circular describes the Karos solder torch, a combination gasoline blow torch and self-heating soldering iron. This has five removable copper tips of different shapes for special work. It is claimed to operate four hours on ½ pint of gasoline.

James G. Biddle, 1211-13 Arch Street, Philadelphia, Pa.—Megger and Bridge-Megger testing sets are described in catalog No. 985 recently issued. Several pages are devoted to an exposition of "Insulation and the Measurement of Its Resistance," which is illustrated by curves and charts. In addition the construction of the equipment and general directions for using, with connection diagrams, are included.

B. F. Sturtevant Company, Hyde Park, Boston, Mass.—Catalog No. 271 contains about 80 pages of tabulation on the dimensions, capacities, horsepower and other performance ratings on the various types of multivane fans—design 3. Multivane fans are designed to give a high capacity from a small diameter fan operated at high speed.

The Climax Motor Devices Company, Chagrin Falls, Ohio—A recent folder describes the construction and operation of the Climax cord disc coupling for the direct connection of motor to machines.

The Electric Motor & Engineering Company, Canton, Ohio—Catalog No. 3, sections 2 and 3, describes and illustrates the line of panel boards, switchboards, steel cabinets and specialties manufactured by this company.

The Electric Storage Battery Company, Philadelphia, Pa.—A 28-page booklet entitled, "Facts for Consideration in Selecting a Battery for Industrial Truck and Tractor Service," is especially interesting to users or prospective users of this equipment. This calls attention to the particular requirements and essential qualities necessary in a battery to attain maximum efficiency and economy in the special duties involved in industrial use.

Everhot Manufacturing Company, Maywood, Ill.—The Everhot self-heating soldering iron is covered in a recent folder. Several removable attachments, or soldering tips, are specially adapted to the electrician's work. The tips are attached to the end of a special gasoline torch.

The Godfrey Conveyor Company, Elkhart, Ind.—Plants which have coal storage problems will be interested in a booklet on Godfrey conveyors which are used to handle coal to and from storage. When reclaiming from open storage a clamshell bucket is used.

Kimble Electric Company, 634 North Western Avenue, Chicago, Ill.—Bulletin No. 250, entitled "Controlled Ventilation," describes the application and performance of Kimble variable-speed, reversible motor on a propeller fan set in an opening in a wall for industrial ventilation.

Electric Arc Cutting and Welding Company, 152-8 Jelliff Avenue, Newark, N. J.—This company is distributing a leaflet which contains cost records and a description of the method of operating the transformer rivet cutter for removing rivet heads and for other cutting work.

The Cutler - Hammer Manufacturing Company, Milwaukee, Wis.—Recent literature announces a new tool-handle switch for electric drills and similar appliances.

Ilg Electric Ventilating Company, 2850 North Crawford Avenue, Chicago, Ill.—A 16-page booklet on "Self-Cooled Motor Propeller Fans" describes the construction of the Ilg fan and its motor, giving particular attention to the method of ventilating and cooling the motor. Performance tables and special illustrations of industrial applications are included.

Burke Electric Company, Erie, Pa.—Bulletin 125 covers the engine type of alternating-current generators. Details of the construction are illustrated and described.

The Westinghouse Electric Manufacturing Company, East Pittsburgh, Pa.—Folder 4,500 recently issued, describes four new types of safety motor starters (WK-10, 20, 30 and 100) with capacities ranging from the smallest motor up to those of 15 hp., 550 volts. All types are equipped with a device for locking the switch in the "off" position to protect those working on the machines. All starters are of the single-throw, quick-make and quick-break type.